THE GLASS INDUSTRY

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A. C. S. TO CELEBRATE GOLDEN JUBILEE AT CHICAGO

The American Ceramic Society will hold its 50th Annual Meeting-Golden Jubilee in Chicago from April 25 to 30. The Palmer House will be headquarters for what is predicted will be the largest Annual Meeting in the history of the Society. Registration will start on Sunday, April 25, and of unusual interest this year will be the Golden Jubilee Exhibit of more than sixty manufacturers of varied products used in the different branches of the ceramic industry. The entire Palmer House exhibition hall has been reserved for the exhibit.

The Sunday evening reception will feature as a highlight a talk by Bruce Thomas, nationally known traveler and lecturer. Mr. Thomas has recently returned from Spain where he gathered material for his lecture, "Ceramics in the Cradle of Conflict—Spain." A brief musical program will follow during which the Chicago Association of Commerce Glee Club will sing.

At the General Session scheduled for Monday, the 26th, A. W. Davidson, Scientific Director, Research Laboratories, Owens-Corning Fiberglas Corporation, will deliver a talk, "Fiberglas: What, Why, Where, When?". His discussion will describe the versality of Fiberglas, an outline of its physical and chemical properties and illustrations of the diverse markets in which Fiberglas is used. Many different forms of Fiberglas materials and typical applications will be shown.

The Ceramic Education Conference will also be held on Monday. In addition to the Panel Discussion on Ceramic Education, there will be two other discussions presented: one by Dr. Howard L. Beirs, President, Ohio State University, "Place of the Large Universities in Technical Education," the other address presented by Dr. A. I. Andrews, Head, Department of Ceramic Engineering, University of Illinois. His subject will be "Departments of Ceramic Education and Their Work at the Present Time."

Tuesday evening will be devoted to the Jubilee Jamboree which will be held in the Grand Ballroom of the Palmer House. Arrangements are being made for a good floor show after which members and their guests will have an opportunity to dance to the music of a popular dance band. Free tickets to the Grand Entertainment will be issued at the time of registration.

The Annual Banquet will also be held in the Grand Ballroom, but on Wednesday, the 28th, induction of new Officers, presentation of new Fellows and awarding of the Binns Medal are some of the events on the program.

Thursday forenoon has been set for the Session on Industrial Relations. Scheduled for this meeting is "Management Problems in Industrial Relations" by Gilbert F. McConnell, Mosaic Tile Company, Zanesville, Ohio; "The Unions' Problems in Industrial Relations" by James M. Duffy, President, National Brotherhood of Operative Potters, American Federation of Labor, East Liverpool, Ohio; and "Common Sense in Industrial Relations" by William N. Margolis, Assistant Director, Federal Mediation and Conciliation Service, Washington 25, D. C., in which the functions and activities of the Federal Mediation and Conciliation Service are described. Particular emphasis is placed on that phase of the agency's work with preventive measures which can be taken to minimize labor difficulties.

A program of activities for the ladies attending the Meeting has been arranged including trips to Marshall Fields', The Art Institute, Field Museum, Harding Museum and other points of interest.

The Camera Club will hold its Exhibit in the Ballroom Foyer. Entry blanks and conditions of entry are available on request. Awards will be as follows:

American Ceramic Society Prizes: The Board of Trustees of The American Ceramic Society has again authorized cash awards of $25, $15, and $10 for the three best industrial photographs having a ceramic interest. The Society will have prior publication rights on all photographs submitted in this Division.

Frazier Award: The Frazier Award will be made as usual to the outstanding photographic print in the Ceramic Camera Club exhibit. The award may be won only once. Any member so signalized a second time will receive a cash award in lieu of the trophy.

The Society does not reserve publication rights on the Frazier Award or any other presentations of the Ceramic Camera Club.

Vontury Award: The Vontury Award will be given to the best print in which a ceramic art object, recognizable as ceramic, is an essential part of the picture.

Mexican Award: A "Mexican Award" will be given by A. F. Rodriguez, Monterrey, Mexico, to the outstanding print with a ceramic interest.

Other Awards: First, second and third-place ribbons will be awarded to the winning prints in Industrial and Pictorial Divisions.

Color Section Awards: First, second, and third-place and three honorable-mention awards will be given to the best 2- by 2-inch color slide transparencies.

Plant trips, an old and popular feature of past A.C.S. Meetings, will be resumed this year. Complete information is not available on this activity as this issue goes to press. However, glass men may find some of the trips of interest. Plant trips thus far planned are as follows: *Thursday, April 29*, Design Division and Women's Plant Trip: Haeger Potteries, Inc., Dundee, Ill.; and Structural Clay Products Division: Streator Brick Co. and Streator Drain Tile Co., Streator, Ill. *Friday, April 30*, Forenoon, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.; Forenoon, American Stove Co., Harvey, Ill.; Afternoon, A. O. Smith Corp., Kankakee, Ill.; Forenoon, Harbison-Walker Refractories Co.; Afternoon, Inland Steel Co.; and Afternoon, Illinois Brick Co., Blue Island, Ill.

Following is presented the daily schedule of the 50th Anniversary Meeting:

SATURDAY
12:30 P. M. Board of Trustees
6:00 P. M. Dinner, Board and Committee Members

SUNDAY
8:00 A. M. Fellow Breakfast
12:00- 2:00 P. M. Ceramic Educational Council
2:00- 5:00 P. M. Institute of Ceramic Engineers
8:00-10:00 P. M. Reception

MONDAY
9:30- 9:45 A. M. Business Session of The American Ceramic Society
10:00-11:15 A. M. Demonstration
11:15-12:00 A. M. Orton Lecture
12:30 P. M. General Luncheon
2:00- 5:00 P. M. General Session
2:00- 5:00 P. M. Women's Reception

TUESDAY
9:00- 5:00 P. M. Division Meetings
8:00 P. M. Student Speaking Contest
9:00 P. M. Grand Entertainment

WEDNESDAY
9:00- 5:00 P. M. Division Meetings
6:30 P. M. Banquet and Dance

THURSDAY
9:00- 5:00 P. M. Division Meetings
1:00- 5:00 P. M. Board of Trustees

FRIDAY
Plant Trips

Committee C-14, American Society for Testing Materials under the Chairmanship of Dr. Louis Navias, will meet Thursday afternoon, the 29th, i tn ehGrand Ballroom at 2 P.M.

In addition to the detailed program of the Glass Division which follows, abstracts of a few papers of special interest to glass men from the Refractories Division and the Materials and Equipment Division are also given. The regular daily program of the Glass Division papers follows:

GLASS DIVISION PROGRAM

Tuesday Forenoon, April 27, 1948
9:30 A.M.-12:30 P.M.
Palmer House: Grand Ballroom

1. Effects of Cerium Oxide on Spectral Transmission of Some Experimental Glasses. *By James A. Kapnicky and W. A. Koehler: West Virginia University, Morgantown, W. Va.*

A number of samples of soda-lime, borosilicate, and flint glasses were prepared. The composition of the samples of each type was varied by the use of different percentages of cerium oxide as a glass constituent. The spectral transmission of each sample was determined over the range 250 to 1000 mμ, and transmission curves were plotted.

2. Transmittance of Near Infrared Energy By Some Three-Component Glasses. *By J. M. Florence, F. W. Glaze and C. H. Hahner: National Bureau of Standards, Washington 25, D. C.*

Three-component glasses have been prepared containing silica and two of the following oxides: Li_2O, Na_2O, K_2O, CaO, SrO, BaO, and PbO. The transmittancies of these glasses for infrared energy at wave lengths 0.8 to 6.0 microns have been measured. Glasses containing BaO do not have as high absorption in the region of 2.7 to 3.0 microns as glasses containing other oxides. This improved transmissivity is believed to be directly affected by the lower water content of barium glasses.

3. Transmission Changes in Glass under Ionizing Radiation. *By Frances Britt: Corning Glass Works, Corning, N. Y.*

Transmission studies over wave lengths from about 0.2 to 4.0 microns have been made on a number of glasses after exposure to Xrays. There is a decrease in transmission over a wide range of wave lengths with greatest changes in the near ultraviolet and short wave-length region of the visible spectrum. Glasses reach a saturation color after which there is no apparent change with continued exposure. In general the color is removed readily by temperatures of about 200°C. or by ultraviolet radiation although the rate of fading differs for various glasses. Thermoluminescence is observed on heating. The processes appear to be completely reversible. The hypothesis made by De Boer with reference to color centers in alkali halides seems to be applicable to glasses; i.e., a color center is a region in which a missing negative ion has been replaced by an electron.

4. New Glasses for Absorption of Harmful Radiations. *By Joseph J. Rothermel, Kuan-Han Sun and Alexander Silverman: (J. J. Rothermel and Alexander Silverman), Department of Chemistry, University of Pittsburgh, Pittsburgh 13, Pa.; (K.-H. Sun), Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.*

The addition of elements not previously used has made it possible to produce new glasses having higher absorption for harmful X radiation than those now available. The behavior of such glasses is discussed in terms of the nature of the elements added.

5. Photographic Report of Some Crystalline Phases Found in Soda-Lime-Silica Glasses. *By E. C. Hagedorn: General Research Laboratory, Owens-Illinois Glass Company, Toledo 7, Ohio.*

This report is confined to approximately fifty photomicrographs of the following phases: devitrite, tridymite, cristobalite, diopside, wollastonite, and pseudowallastonite. Approximately two-thirds of these are black and white, with the remainder in color. These photographs are intended to illustrate the general characteristics as well as some of the peculiarities of these crystalline phases at various magnifications. The compositions of the glasses in which the phases occurred accompany the photomicrographs.

Tuesday Afternoon, April 27, 1948
2:00 P.M.-5:30 P.M.
Grand Ballroom

6. Electrode Function (pH Response) of Soda-Silica Glasses. *By Gerald F. Rynders, Oscar H. Grauer and Donald Hubbard: National Bureau of Standards, Washington 25, D. C.*

A series of Na_2O-SiO_2 glasses covering the composition range from 51.3 to nearly 100% of silica has been studied for durability, hygroscopicity, glass electrode function and apparent response to Na^+. The durability curve at pH 4.6 exhibits three distinct regions of durability characteristics: (1) below 81% of SiO_2 where the glass is carried into solution, (2) between 81 and 89.5% of SiO_2 where differential solution of the constituents of the glass leaves a swollen silica-rich layer and (3) a region of improved durability with fused silica as the end member. Electrodes prepared from glasses of low-silica content having poor chemical durability and high hygroscopicity exhibited large voltage departures and approached the behavior of a "punctured" mercury-filled electrode, which in turn approximated the performance of a saturated calomel half cell. The apparent response to Na^+ ranged from 339 mv. per pNa to 9 mv. per pNa for the glasses containing 56.6 and 82.6% of silica, respectively.

7. Low-Temperature Viscosity of Alkali-Silicate Glasses. *By J. P. Poole: Glass Science Research Foundation, State College, Pa.*

With the improved technique, precision measurements of the viscosity of soda- and potash-silicate glasses were made over a range of 10 to 40% alkali oxide. The compositions of all glasses were determined by analysis. The practical aspects of the results are discussed.

8. Systematic Study of Effect of Oxide Constituents on Low-Temperature Viscosity of Silicate Glasses. *By James P. Poole and Maxwell Gensamer: Department of Mineral Technology, The Pennsylvania State College, State College, Pa.*

Experimental low-temperature viscosity data obtained by the fiber-elongation method are presented for simple three- and four-component alkali-alkaline earth-alumina-silicate glasses. In this study, soda, potash, calcia, magnesia, strontia, baria, and alumina are systematically substituted molecularly for silica and each other. A wide range of compositions was studied, including most commercial silicate glasses. Factors, formulas, and charts derived from experimental data are presented which predicted the results of the viscosity of soda-lime-alumina-silicate glasses within about 1%.

9. Measurement of Thermal Diffusivity in Glass. *By R. B. Randels: Corning Glass Works, Corning, N. Y.*

In transient heat-flow problems, the thermal property of greatest importance is generally the diffusivity. Although this property can be calculated if conductivity, specific heat, and density are known, it may be directly measured more easily than the steady-state conductivity. The solution of the transient heat-flow problem in a circular cylinder which is suddenly heated or cooled indicates that it is sufficient to measure two temperature differences and the elapsed time between the two observations. Results have been obtained for several glasses of widely varying composition using rapidly boiling water as the heating bath. The technique is extremely simple and requires only suitable samples in the form of heavy-wall capillary tubing, thermocouples, a potentiometer, and a stop watch.

10. Changes in Refractive Indices and Liquidus of a Dense Barium Crown Glass Containing Lanthanum Oxide Produced by Partial Substitution of Various Oxides. *By E. H. Hamilton, O. H. Grauer, G. W. Cleek and C. H. Hahner: National Bureau of Standards, Washington 25, D. C.*

The addition of La_2O_3 to barium crown optical glasses is desirable if glasses with high refractive index and low dispersion are desired. As the amount of La_2O_3 in the glass is increased the liquidus temperature of the glass increases rapidly. Glasses with large amounts of La_2O_3 must be cooled rapidly to avoid devitrification. Series of glasses were made in which an oxide, such as CaO, ZnO, Al_2O_3, ZrO_2, and ThO_2, progressively replaced either the BaO or La_2O_3. The refractive indices for the C, D, F, and G′ lines and the liquidus temperature of each glass were determined. Glasses were produced with n_D from 1.665 to 1.729, v of 57.0 to 51.5, and liquidus temperatures from 900° to over 1200°C. The presence of up to 8 mole % of ZrO_2 had little effect on the liquidus temperature, but the tendency to devitrify was decreased. A minimum was found on the liquidus curves for glasses containing 4 to 5 mole % of ThO_2.

Wednesday Forenoon, April 28, 1948
9:30 A.M.-12:30 P.M.
Grand Ballroom

11. Some Recent Developments in American Glass Manufacture: III, 1938-1947 *(Amer. Ceram. Soc. Bull.,* **26** [11] 367-77 1947). *By Alexander Silverman: Department of Chemistry, University of Pittsburgh, Pittsburgh 13, Pa.*

This paper, illustrated with colored slides, covers the various branches of glass manufacture and the developments which have been made in the last decade.

12. Effects of Some Minor Constituents on Glass Melting. *By James P. Poole, Dorothy P. Enright and Paul A. Marshall, Jr.: Division of Ceramics, The Pennsylvania State College, State College, Pa.*

This paper discusses the effects of sulfate, barium oxide, and fluorine on the meltability and fining characteristics of both amber and flint container glasses. These effects were measured by seed count, visual examination, density determinations, and low-temperature viscosity measurements. Curves of fining time and viscosity characteristics are given. The testing procedures were unique in that 40 pound melts were made and the results were found to be applicable to continuous glass-tank operation.

13. Characteristics of a Batch Change in a Continuous Tank Furnace as Determined By Measurements of Density and Homogeneity. *By Henry Moore and A. K. Lyle: Hartford-Empire Company, Hartford, Conn.*

The rate of change of glass following a batch change is represented by density data. These data are shown to fit the equation

$$N' = 100 - 100/e^R$$

N' = percentage of new glass.
R = ratio of total tons of new glass added to total tons of glass in furnace. $e = 2.718$ (Naperian base).

The first evidence of the batch change is shown to vary between 2.5 and 13 hours, depending on the position of the feeder. The worst cordiness occurs when the batch change is 50% effective.

14. Some Examples of Radioactive Tracing in Glass Technology. *By Stig A. Lindroth: University of Illinois, Urbana, Ill.*

In 1929 Hahn suggested the use of radioactive emanation-producing tracers for investigations of powders. The method has been applied in (1) determination of surfaces and surface changes (e.g., melting) and (2) the study of diffusion phenomena in relation to transformations and chemical reactions.

Preliminary investigations on glass batches, started at Chalmers Technical University, Gothenburg, Sweden, have indicated the usefulness of the method. In this application of the procedure, small samples of glass batch (0.2 gm.) were treated with radiothorium nitrate solution dried and sieved, and heated at a constant rate of 10°C. per min. up to 900°-1000°. The release of thorium emanation atoms as a function of the temperature is measured by their ionizing effect on a nitrogen current passing the sample into an ionization chamber connected to an amplifier and a sensitive galvanometer.

The method has been used in the study of (1) sodium carbonate, calcium carbonate, and a soda-lime-silica glass batch; the melting point of Na_2CO_3, the aragonite-calcite transformation, and the dissociation of $CaCO_3$ are clearly brought out; the emanation curve of the glass batch shows also the melting point of Na_2CO_3, referring probably to

(Continued on page 218)

RAW MATERIALS PROCUREMENT PROBLEMS IN THE GLASS INDUSTRY

By C. L. RICE, Purchasing Agent
Owens-Illinois Glass Co., Toledo, Ohio

Considering the things which have happened to purchasing people during and since the war, the reference to problems in the title of the discussion which has been assigned to me seems quite appropriate. While I recognize that buying conditions in our business are somewhat better today than they were a year or two years ago, we are not without problems and I don't presume that we shall ever be entirely free from them. In this discussion I should like to talk about some of the basic problems as contrasted with war time problems, which are characteristic of the glass industry and which I feel determine to a large extent our competitive position in industry, and which will dictate to a great degree much of our future planning. It would be possible to select a number of items for this discussion, but for the production group I assume glass making materials would be of most interest and I shall talk about those which are essential for the operation of a glass plant and will include refractory materials, fuel, and packaging materials. I include these latter three items on the theory that it is necessary to process materials to produce a finished product and, when made, a package is required to get it to its markets.

In order to visualize the sales and purchasing operations of the glass industry from a geographical standpoint, I ask that you consider the United States divided into five districts. These districts comprise an eastern district, a central district, a southern district, a western district, and a Pacific Coast district. The eastern district includes the New England States, New York, Pennsylvania, and those states along the eastern seaboard north of Virginia. The central district includes Ohio, Indiana, Michigan, West Virginia, and Kentucky. The southern district includes all of the states south of the Mason-Dixon Line and east of the Mississippi River with Louisiana added. The western district includes all of the states between the Mississippi River except Louisiana and the Rocky Mountains including Wisconsin and Illinois. The Pacific area includes the three states bordering the Pacific, plus Idaho, Nevada, Utah, and Arizona. These are mainly sales districts and while they represent glass container sales, I think the statistics which I will use in connection with them parallel quite closely the national statistics for the glass industry.

Starting in the East, my figures show 40% of sales in this area. The central district sales percentage is 20%. The southern district is 10%, the western district 20%, with 10% on the Pacific Coast. Using these same districts to show the location of purchasing units it is noted that 13% is located in the eastern area, 44% in the central area, no per cent in the southern area, 30% in the western area, and 13% in the Pacific Coast area. It is obvious from these comparisons that except for the Coast sales and production are very much out of balance. For further comparison, when we take the materials which are necessary to maintain these production units and see where they come from in relationship to these areas, we get the following pattern:

	Sales	Production	Sand	Soda Ash	Lime Products	Feldspar	Refractory Materials	Coal	Oil	Gas	Paper
Eastern	40	13	14	4	11	1	22	2	—	4	4
Central	20	44	42	61	33	9	18	84	—	24	20
Southern	10	0	—	19	—	45	—	—	—	21	44
Western	20	30	32	5	44	45	60	14	87	41	20
Pacific	10	13	12	11	12	—	—	—	13	10	12

It does not take a great deal of analyses of these figures to see that the problem of the buyer in the glass industry is very much a problem of geography and transportation, and since it is not practical always to move glass plants to material sources, our objective is to find usable materials within the shortest freight ranges and with the most economical delivered costs to our producing plants. If it were possible to find an ideal plant location, it would be on top of a glass sand deposit and next door to a soda ash plant, a limestone quarry, a feldspar deposit, and a corrugated container plant, with a natural gas line in front of the premises and enough customers down the street to keep the plant operating 12 months each year. I don't know too much about pricing practices in other lines, but in our business we are subject to both inbound and outbound freight and location of suppliers is of major importance.

Taking the question of accessibility to our plants as a basic problem of the glass plant buyer, it seems to me that it would be of interest to this group to review the status of major suppliers as they exist today and see what is ahead of us for the next year and succeeding years. I shall not mention suppliers by name, but I do acknowledge with appreciation the help of several of them in the preparation of the material for this paper. I should like to make it clear that in the predictions which will follow I am taking into account the conditions as I see them today without regard to what may happen in the event that the Marshall Plan or other plans for the relief of Europe are passed by Congress.

My figures show that the glass container business has increased approximately 120% in grossage during the past 10 years. I don't know if this percentage of increase has been reached by other branches of the industry, but I am sure that all glass manufacturers have had a substantial increase over the past 10 years. Our estimate for next year has been set at about 10% above 1947. This increase in production means, of course, increases in demands for materials and the question quite naturally follows: "Will the suppliers be able to keep up with these demands and, if not, will sufficient materials be available from new sources to meet the estimate?"

Presented before the Ninth Conference on Glass Problems, University of Illinois, Urbana, Illinois.

As was stated in the introduction, my responsibilities are confined entirely to purchasing activities and for this review I should like to consider you as an operating or manufacturing committee and I shall make my report as your purchasing agent.

In every glass batch formula which I have ever seen sand comes first, so I shall start with sand. There are about 15 companies producing glass sand in the United States. The record of production of these companies during the past 10 years shows an increase of approximately 92%. Glass sand as most of you know, is available in rather definite areas in the United States. Beginning in the extreme East, the largest production is in New Jersey. Sand in this area lies in open pits a few feet below water level and production is accomplished mainly by dredging and pumping. This sand is in natural grain formation and lends itself quite readily to commercial treatment. The main impurity is iron oxide, which most operators remove by the use of concentrating tables. At today's rate of consumption this eastern production is just about keeping up with demand.

Moving West, the next area of glass sand production is along the Appalachian Mountains with workable deposits extending from Pennsylvania to Georgia. The largest of these is in West Virginia and Maryland near Berkeley Springs and Hancock. This sand is of rock formation and production requires quarrying, crushing, washing, and screening. From this area is produced some of the finest glass sand in the East and the quantities which are available are for all practical purposes unlimited.

Further West are deposits in Virginia, western West Virginia, Ohio, Indiana, and Michigan. These deposits as a rule are higher in iron oxide than the ones in the East but some very fine production has been made with the use of acid treating and flotation. Grain size from most of this area is excellent.

The next area of production is in Illinois, Wisconsin, and Missouri. Again some of the finest glass sands produced in the U.S.A. are from this area. Operating conditions for the most part are favorable and the supply, as in the Appalachian area, is unlimited. There are also sands in Colorado but freight rates prevent them from competing with eastern producers.

On the West Coast glass sands are available mainly from Nevada and from deposits in California. These sands to a large degree are not as usable as the eastern sands and require a great deal of processing and treating. Our Company is now operating two sand plants on the Coast, one in the Del Monte area and one south of Los Angeles. At both of these operations the cost of removing impurities is quite excessive. There are millions of tons of low grade sands in the East and on the Pacific Coast which are outside the specifications for glass sand and a successful method of making these sands available for glass production would be a major change in the industry. In summary, there are sufficient sands from existing producing areas to meet all expected demands in the glass industry for more years than any of us need to be concerned.

Soda ash is a somewhat different problem. As of today, there are 10 producing companies manufacturing glass grades. The location of plants in the East is determined mainly by the location of salt deposits. In the West production is mainly from dry lake beds. In the East the largest producing areas are near Syrcause, New York, Detroit, Michigan, and northern Ohio. In the Southwest the production is near Baton Rouge and Lake Charles, La., and Corpus Christi, Texas. In the West production is mainly in California east of the Sierra Nevada Mountains and recently a new development has been opened up in western Wyoming. Annual production of soda ash prior to the war was approximately 4,300,000 tons. It is estimated that new capacity now under construction will increase the annual output to 5,000,000 tons by the end of 1948. Of this production approximately 1,800,000 tons will be in dense grades. This figure does not include 200,000 tons which will be produced in California and Wyoming. Demand for soda ash during the war exceeded the production and, as most of you know, soda ash became the No. 1 headache for the glass plant purchasing agent. A great job was done in keeping soda ash off allocation and the industry, in spite of shortages, kept their distribution on a very fair basis.

Lime and limestone are the next items to be considered. The main buying problem with lime products is that glass lime and limestone are, to a large degree, by-products for the producers. I don't know how many producers there are making glass grades of lime and limestone, but we have 12 suppliers on our books. As most of you know, most lime and limestone production is for building, agricultural, steel and for road construction. This places the glass maker quite a way down on the list of preferred customers, and at some disadvantage. Pennsylvania, Ohio, and West Virginia, Missouri, and California produce most of the grades used by the glass industry, which production includes both dolomitic and high calcium lime. I shall not attempt to lead any discussion on the relative merits of Dolomite versus high calcium, but for all practical purposes there is an abundance of limestone in this country. An adequate supply is mainly one of processing and in some instances the quantities required by individual glass plants are too small to offer the necessary inducement to the operators to put in new equipment to produce the grades needed. There is also the question of preparation. There doesn't appear to be too much uniformity in practices between users on grain sizes which are best suited for the glass trade and this limits the supply which could be made more available if standards between various users could be adopted.

The last batch item which we will consider is feldspar. This does not represent a very large tonnage when compared to some of the other batch materials, but on the other hand, the total requirement is not large. There are about 7 or 8 producers in the field. The New England states supply some tonnage; North Carolina, eastern Tennessee, and Virginia are the largest producing states in the East, with South Dakota and Colorado the big producing states for the Midwest. In California feldspar exists with the sand as a batch item and is not purchased as such. Again as in some of the other materials, the glass manufacturer is handicapped with some rather close specifications when buying feldspar. Our check of the expected production for the coming year indicates enough spar available for any needs, assuming usage continues at the anticipated rates.

The information which I have on refractory materials applies mainly to the finished materials and not to the materials required to manufacture the blocks. The largest

producing areas of refractory materials are in Pennsylvania, Ohio, Kentucky, and Missouri. A study of furnace lifes during the past several years shows very clearly that a great deal of advancement has been made in the quality of refractory materials, which advancement is due in no small part to the work of the refractory people. The industry's history of furnace life shows an increase of some 50% or more over a 10 year period, with better than 10% improvement in furnace pulls. There are others who are better qualified to talk on refractory materials than I am but so far as the supply is concerned, reports which I have received would indicate these are adequate to meet the rebuilding schedules which can be expected in the industry during the next 12 months.

Fuel breaks down into 3 sections: natural gas, fuel oil, and coal. Prior to 1930 coal represented the major fuel for most glass plants in the East and Midwest. Beginning in the late 1920's and early 1930's natural gas lines were extended into the East and in the years immediately prior to the war, natural gas had replaced coal to a large extent, especially in the midwestern states. Since pipe lines were mainly financed by bond issues it was the common practice of the pipe line companies to arrange contracts for the sale of definite quantities of gas for industrial users and distributing companies even before these lines were built. Those contracts helped in securing the financing for the lines and usually price was equal to the price of coal on an equivalent BTU basis, or slightly lower. For the most part these contracts were for firm gas and whenever interruptible contracts were written, as in the case of boiler fuel, the prices were at dump rates. After the lines were in operation the gas companies, quite naturally, began to enlarge the sale of gas to domestic users as such gas demanded a higher price than the gas sold for industrial use. These sales to domestic users were not too much of a threat in the late 1930s although some areas began to feel curtailments as early as 1938. With the war, however, and the priorities system which applied to war industries and the terrific increase in domestic usage, the glass users were pushed further down the list and practically all areas were placed on a curtailment basis during cold weather, and all contracts were changed by the gas companies from firm contracts to interruptible contracts. I cannot see any marked improvement in the supply of gas for glass plants in future years, and as the supply becomes less, the price for industrial gas will increase.

Fuel oil also presents rather an unhappy outlook. In an attempt to provide some protection during gas curtailment in the winter months, most industries in recent years who have been using gas as a major fuel, have turned to fuel oil. This has placed an unprecedented demand on fuel oil for industrial use, which, coupled with the limitations in the devolpment of new oil fields, has brought about an acute shortage. New developments have been retarded due to shortage of pipe and drilling equipment. Oil is also one of the items which would be most affected in any aid to Europe program. So far as the glass maker is concerned, oil has become a luxury fuel and unless demands can be eased by the development of new fields, or some relief is brought about in world demand, fuel oil is rapidly being forced out of the reach of the glass maker as a melting fuel. I see no marked relief for at least two or three years if then. Coal is the only remaining fuel of unlimited supply. Estimates place reserves in the United States at 2,500 to 3,000 years. What if it is only 2,000 years, that should be enough to satisfy everyone in the industry. Unfortunately, coal production has been subject to all the aches and pains of industrial turmoil both within and without the industry. It is unfortunate that coal producers have been content to just bring coal above ground and let someone else look after its end use. The oil companies never made that mistake and are constantly developing new methods for the use of their products. Until very recent years all developments for the use of coal came from outside the industry. Coal still offers the greatest potential source of fuel in this country and it is my prediction that the trend of industrial fuel usage will begin back to coal in a very few years. Some one, some day, will be smart enough to get the BTUs out of coal in the ground and bring them to industrial plants without the present labor and transportation costs which are necessary under today's methods.

In summarizing on fuel, gas will be in no better supply in the future than at present. Oil is becoming less and less available and will take higher prices. Coal will eventually return as the work horse in industrial plants.

As our last item I shall consider paper or containerboard as it is known in the paper industry. I am considering only corrugated packages as I assume that by far the largest percentage of glass ware is packed in corrugated today. Paper is a story all by itself. The paper industry is No. 7 on the list of big businesses in this country. About 1924-1925 the first kraft board from the South, made from southern pine, was placed on the market. This opened up an entirely new field for corrugated cartons. Prior to that time cartons had been made mostly from jute, which is a board produced from waste papers plus wood pulp. With all kraft pulp from the South the weight of the container was reduced and the strength increased. Today the single kraft mill of 1924 has grown to about 20 mills and graft has become the No. 1 material for corrugated cartons. The expansion of kraft mills from 1933 to 1938 created some surplus, the result of which was a very vigorous competitive fight between kraft and jute. Prices for containerboard during that period were at an all time low. With the war, however, the situation changed rapidly and while prices were frozen by O.P.A., the supply of kraft became very much in demand as it was the most suitable material for water proof packages for overseas shipment. Kraft, of course, came under priority regulations and very little was left for domestic usage. Since the war a large number of kraft producers have entered the corrugating business and the supply of kraft roll stock available to the independent fabricator has been very much limited. With the lifting of O.P.A. prices there has also been a very sharp increase in the price of all containerboard and as far as I can determine, there is nothing in the immediate future which will change this situation. Before the war considerable Scandinavian pulp moved into this country, which helped to keep domestic prices down, but at the present time, very little Scandinavian pulp comes into the American market and as demands for all grades of paper have increased tremendously over prewar demands, there is little hope that any new production from existing mills will be sufficient to affect the

(Continued on page 230)

ORIENTATION OF THE SURFACE OF GLASS

By JOHN F. DREYER and CHARLES W. ERTEL

A thin amorphous layer capable of orientation by rubbing can be developed on the surface of many solid substances.[1] Glass has this characteristic to a great degree and it is quite easy to develop a unidirectional film on its surface, the directional character of which can be controlled by the direction of rubbing. This phenomena was realized a number of years ago but the technique was not completely developed. By proper staining, the intimate history and condition of this surface can be determined. Improved tools and simplified techniques have been developed recently for the study of such surface orientation.

A light polarizing solution which works by a new principle is used as the testing medium. This solution, "Polacoat,"[2] was developed for the production of light polarizing filters on glass, plastics and metals.[3] It shows promise as an indicator of surface orientation. The solution consists of certain dichroic materials which, in drying, go through the nematic liquid crystal phase.[4] This phase is sensitive to the orientation of the surface with which it is in contact, and takes on that orientation during solidification.[5] Drying the solution freezes the alignment of the film so that a permanently visible record of the orientation of the surface results.

The dichroism of the film produces an oriented polarization which can be viewed readily by means of a second polarizing filter. This polarization is visible by means of transmitted reflected light. By this technique, there can be seen a marked difference between a surface which has been polished and one which has been abraded. With good polishing, the resultant polarization is uniform to the naked eye, and when viewed under the microscope. Fig. I shows a view under the microscope at 175 diameters magnification of the polarized film on a plate which has been oriented (by uniform polishing) with one-half in one direction and the other half at right angle to the first half. Uniformity of light transmission indicates regularly oriented surface underneath.

One can determine whether or not the surface of glass has been abraded or polished even to the extent and direction. Abrasion has a different action on the surface than polishing, as can be shown by this technique, and tends to remove the plastic lever. The result is a furrowed surface when viewed under the microscope (Fig. II). Observation of the surface through a polarized plate shows a non-uniformity which is visible to the naked eye. Whether polished or abrased surface will be produced depends upon several factors. The literature recognizes that for polishing a soft-backed rubbing tool is desirable; the polishing compound should be of fine particle size, and its melting point usually higher than that of glass.[7] Validity of these statements and effects of other variables can be studied readily by this new process. It has been found that the particle size of the polishing compound is most important. Whiting and "Calcene" grades of calcium carbonage produce more surface abrasion than polish, while "Multifles MM" micro milled and "Multiflex" of ultra-fine particle size .03-.04 microns, produce a smooth polish. Rouge of particle size 0.7 microns also gives a smooth polish.

The correct pressure required for polishing will vary with the type of glass and with the particular compound used. It has been found that with black rouge on soda lime glass, sufficient pressure could not be used to cause abrasion with hand rubbing. With commercial grades of Whiting, very light pressure must be exercised. Successive grades of clay containing higher proportions of aluminum oxide were found to require less pressure to develop the polish layer and keep from abrading.

Observations point out some of the factors which can be determined by this process. Further experimentation should be done to carry this work to a satisfactory completion. For some time it has been debatable whether scratches could be flowed over. By using this nematic solution, it may be shown that such is the case and scratches can be covered over. Fig. III shows the results of this test applied to a plate which has been rubbed uniformly in one direction and then rubbed on a small portion diagonally. Previous vertical scratches are still seen

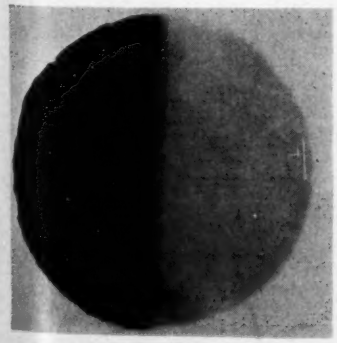

Fig. I.

Fig. II.

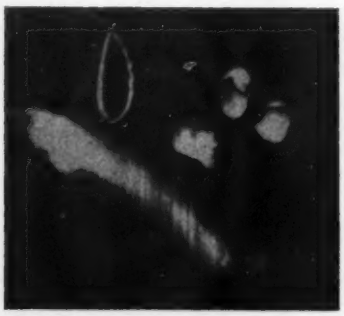

Fig. III.

to be present in this area, and finger prints appear in other areas.

Fig. IV.

For some time, it has been realized that with metals a scratch can be covered by polishing, and can then be made to reappear by subsequent etching. We find that a scratch on glass can be covered in the same way, by polishing, then be seen to reappear when the plastic polish layer is abraded off. Fig. IV shows the results of this test applied to a strip of plate glass which was rubbed crosswise with Whiting. The rubbing with Whiting was not carried far enough to remove all of the marks from the original grinding, but did remove the polish layer and brings out the marks made in producing the plate finish. Fig. V shows these marks magnified 175X.

The technique for application of the test is as follows: First the glass must be cleaned of all greasy and water-incompatible materials. (Use trisodium phosphate or ammonia as the final washing.) It is necessary to wet the base properly. The glass is then laid flat and rubbed with a slurry of the appropriate material, using a felt-faced tool. The slurry is rinsed and gently wiped off, leaving the glass wet. The polarizing solution is then flooded on. Upon drying, a polarizing film results.

In applying the test, certain precautions must be observed, the most important being to see that the glass surface is basic in character when the solution is applied. Acid surfaces prevent orientation of the polarizing film, and result in formation of characteristic nematic threads, illustrated in Fig. VI.[8] Other factors which must be considered are the use of a dust-free area, and reasonably still air for drying the film.

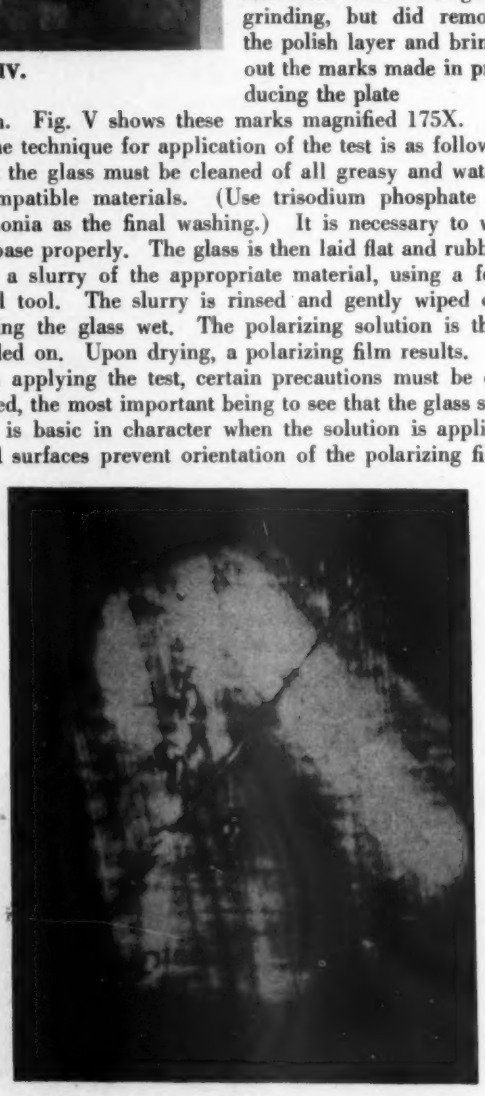

Fig. V.

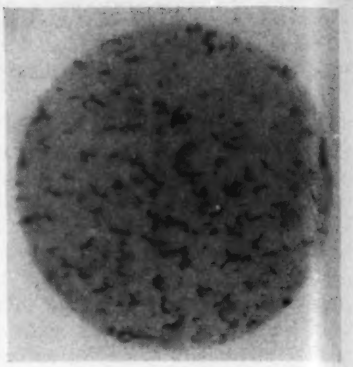

Fig. VI.

All types of glass which have been tested showed the orientation phenomena. Thermoplastics also function in the same manner. Crosslinked thermoset resins such as bakelite do not show rubbing orientation. A peculiar and unexplained effect has been observed on plastics of cellulosic type in that they show polarization in a direction perpendicular to that of rubbing. Metallic surfaces show orientation, but sufficient studies have not been made to determine the characteristic of orientation. For observation on opaque materials, a solution is used which polarizes by reflection, and can be viewed as a mirror.

This process has been used to advantage to detect the history of glass surfaces. It has been found, for example, that the fluorescent tubes of one manufacturer possess a distinctive tread design on the glass surface. It is also of value to show when a surface has been properly polished, or when compounds used are causing abrasion.

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FRENCH GLASS INDUSTRY REPORT

The French glass industry has made an astonishing recovery and the 1947 production figures for certain articles indicate a doubling or tripling in comparison with pre-war output, according to the Information Service of the French Embassy in Ottawa, Canada.

	Production (Tons)	Production Index (1938 = 100)
Uncut mirror and coarse glass..	896	25
Window glass	6,558	206
Cast glass	6,579	286
Molded glass	342	148
Glass fibres	569	—
Insulators	157	31
Bottles and demijohns	42	92
Glass jars, green	20,529	116
Glass jars, white	223	637
Glassware, machine-made	1,222	119
Glassware, hand-made	3,006	86
Containers and flasks, machine-made	1,194	146
Containers and flasks, hand-made	5,440	70
Light bulbs and signs	1,512	71
Laboratory equipment	313	79

FLAT GLASS MONOPOLY TRIAL OPENS IN TOLEDO

THE FLAT glass industry is "The Glass House of Monopoly," according to Curtis L. Shears, Special Assistant to the Attorney General of the Department of Justice. Opening the government's anti-trust suit against eight companies manufacturing plate, window, safety, laminated, tempered, and sheet glass, Mr. Shears called the industry a six-room house comprising rooms of window glass, plate glass, laminated glass, tempered glass, foreign glass and distribution competition elimination.

"The builders, owners and occupants of this glass house are the flat glass family," he continued. "Father PPG is married to Mother LOF. Mother-in-law NGDA first sponsored the union, later served as baby-sitter, and reports to father and mother when the children misbehave. Three children grace the hearthside: their own twins, Fourco and Rolland, and little Franklin, adopted son of European friends. An uncle, American Securit, and a cousin, Corning, helped build the tempered glass room."

(Here the court interrupted to ask: "Is Blue Ridge an infant?")

"A widowed aunt, AWG, once married to a sailor named Lubbers Line, who passed on in 1928, now assists in the management of certain portions of the house. Last comes Blue Ridge, the dog, without whom no home is complete," continued Mr. Shears.

"Not all members of the family are permitted in all rooms of the house. The twins, Fourco and Rolland, are permitted in the window glass room only. This serves as the nursery, where they for some time romped with their little playmates, but finally, encouraged by their parents, the twins drove all of their playmates out of the house, save Blackford, a submissive child.

"Little Franklin is permitted in the plate glass room as long as he behaves and doesn't want too much of the plate glass cake. Aunt AWG helps in managing two rooms, the window glass room and laminated room. Blue Ridge—Mother LOF's pet—after misbehavior in the plate glass room, is not permitted in the house at all, so Mother takes good care of Blue Ridge in a specially constructed dog house. PPG, LOF and NGDA are, of course, permitted in all its rooms. Friends of the family drop in from time to time to visit in the laminated room but must pay visitors' fees to Father or their presence is made unwelcome. LOF and the twins represent the family in the social and public relations, PPG having been mentioned unfavorably in court in 1910."

In reply, John T. Cahill, counsel for the defense, said he hoped to take the court into a factory or special exhibit to demonstrate physically the miraculous changes in design technique and products which have occurred in the seventeen years covered by the complaint and thereby demonstrate that "Mr. Shears' house of glass is in fact a house of cards."

Ross W. Schumaker, local counsel for the Pittsburgh Plate Glass Co., after reviewing the technological and economic achievements of flat glass production during recent years, referred to Mr. Shears' "house of glass" as "a remarkable structure of his imagination, as original and daring in conceptual make-believe as a child's doll house; a chapter from Alice in Wonderland—and yet as clever in its fantasy as it is factually unreal and misleading."

Pointing out that monopoly in the plate and safety glass industries is inconceivable in view of the present and potential competition from the automotive industry, Mr. Cahill said that a sense of proportion required that one consider the size of the units the defendant glass companies are compelled to compete against.

"These are the giants of the nearby automotive city of Detroit," he declared, "which are the users of 90 percent of the safety glass and 70 percent of the plate glass. We well know how sharp are the pencils of the purchasing agents of these automobile companies. If these gentlemen felt that they had been the victims of a conspiracy, they would know, under any circumstances, how to take care of such a matter.

"But it so happens that, in addition here, there are potential weapons in their hands available for speedy use if they wish to resume, themselves, the manufacture of glass for their automobiles. The record here will show that Ford Motor Company has been in and out of the glass business in a big way since 1921. Yet it is one of the largest buyers of automotive glass today.

It is a commonplace that the Ford Motor Company would never give up making anything itself which it could make better or cheaper than it could buy on the outside. So, too, with General Motors Corporation. The history of this industry shows that the General Motors Corporation, on several fronts, was active in the manufacture of glass, not only in one or two, but three factories; and that it ran its plants for some years, until finally it was convinced that more effective operation could be conducted by outsiders, and it sold those plants to the Libbey-Owens-Ford Glass Company.

"Now if the glass companies are at a disadvantage in present size in dealing with the automotive companies—and it is apparent that on a comparative basis of assets all these glass companies put together are just pygmies, as compared with the motor manufacturers, how much more so would this be true if the government prayer for relief—taking all factories but one away from each defendant—in this case were carried out."

Stewart S. Wall, counsel for Libbey-Owens-Ford, described the competition between his company and Pittsburgh Plate Glass Company in 1931 to buy the National Plate plant at Ottawa, Ill. from General Motors Corporation. Competitive bidding between the two glass companies increased the price of the plants from $7,500,000 to $9,500,000 and gave General Motors a better price for its glass. "This was a strange conspiracy indeed," he commented.

Leland Hazard, vice president and general counsel for Pittsburgh Plate Glass Company, describing technological advances, said that what the plaintiff charges as man-made facts the evidence of the defense will show to be "machine-made."

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BORIC OXIDE—ITS CHEMISTRY AND ROLE IN GLASS TECHNOLOGY

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PART II

IV. Structural Aspects of Boric Oxide Containing Glasses

1. The Atomic Structure of Vitreous Boric Oxide. It is not much more than ten years ago that accurate information became available concerning the atomic structures of simple glasses. Through the interpretation of X-ray diffraction patterns by Fourier analysis, it is now possible to derive the atomic distribution, interatomic distances and coordination numbers of the atoms in simple substances independent of their state of aggregation. Boric oxide glass was one of the first vitreous materials to which this method has been employed. B. E. Warren, H. Krutter and O. Morningstar found that in vitreous B_2O_3 the boron-oxygen distance is about 1.39 A.U. as compared with 1.36 A.U. in crystallized borates.

The position and the area of the first peak in the scattering curve revealed the B-O distance and furthermore that each boron atom is surrounded by three oxygens. From the boron to oxygen ratio 2:3 and the fact that each boron is bonded to three oxygens it follows that each oxygen must be bonded to two borons. The random network of a B_2O_3 glass is, therefore, built on triangular coordination. Furthermore it has been found that each boron forms the center of this triangle of three oxygens. Each oxygen is bonded to two borons with the two bonds presumably roughly diametrically opposite.

Other peaks of the scattering curve reveal the oxygen-oxygen distance to be 2.42 A.U. and the boron-boron distance to be 2.78 A.U. The above mentioned triangular configuration permits the calculation of the O-O distance and leads to the value:

$$1.39 \times \sqrt{3} = 2.40,$$

which is in excellent agreement with the experimentally found value of 2.42.

Assuming that the borons are bonded to oxygen at an angle of about 180° (diametrically opposite) the boron-boron distance must be twice the B-O distance:

$$2 \times 1.39 = 2.78$$

The same assumption leads to a value for the boron—second oxygen separation of

$$1.39 \times \sqrt{7} = 3.68,$$

which is in good agreement with the experimental value of 3.75 A.U.

The structure of B_2O_3 glass is unique in several respects. It is the only known glass where the central cation has the coordination number three. In other glasses, silicates, phosphates, arsenates, germanates or the complex beryllium fluorides, the central cation is surrounded by four anions. The BO_3 group is a planar triangle, whereas the SiO_4 or PO_4 groups extend into space forming regular tetrahedra.

Properties involving a change in the arrangement of the glass forming groups in space such as viscosity or crystallization were found to be unusual for B_2O_3 glass. It is apparently much easier for the SiO_4 tetrahedra in vitreous silica to arrange themselves to form a crystal lattice. The presence of water greatly accelerates devitrification, once a nucleus has been formed or introduced, because some of the strong B-O-B bonds are replaced by the weaker bonds acting between OH groups and because the decreased boron to oxygen ratio makes possible the formation of groups of higher symmetry. As BO_4 groups form, viscosity decreases and crystallization becomes more probable. One frequently finds the statement that the crystallization rate is low because of the viscosity being high. The viscosity in turn is thought to be primarily a function of the molecular forces. Such a statement is not quite correct. The properties based on diffusion and molecular rearrangement depend on the absolute size and on the symmetry of the intermolecular forces. K. Fajans and N. J. Kreidl pointed out that the mobility of a particle within a liquid is impaired when the field of forces exerted on it by surrounding particles has a low symmetry. Independent of the absolute strength of the forces, a particle can perform a rotational or translational motion without much "activation energy" if it gains by the approach to particles on one side the energy required for removing it from adjacent particles on the other side. The more the particles deviate in their symmetry from that of the sphere, the more difficult becomes the rotational and translational motion. The high viscosity of glycerol, for example, is not due to strong forces acting between the molecules (the melting point of glycerol is 17°C.) but due to their asymmetrical shape. The same holds true for molten B_2O_3. The low melting point (450°C.) indicates that the forces between the BO_3 units cannot be exceedingly strong, but their low symmetry requires a high activation energy for their mobility.

The high activation energy resulting from the asymmetrical shape of the BO_3 unit is one of the outstanding features of B_2O_3 glass. It not only accounts for the high viscosity and for the lacking tendency to crystallize but it delays all molecular rearrangement and thus allows high temperature configurations to be frozen in readily. The density of vitreous B_2O_3 has been determined repeatedly by different workers, but their values scatter over a wide range. The most reliable data range from 1.778 to 1.838. The density of crystalline B_2O_3 is 2.460. The values indicate considerable differences in the "compacting" of the various forms of B_2O_3 due to the sluggish transitions from the chilled to the annealed and compacted glass. As a result the properties of B_2O_3 glass are greatly affected by heat treatment and by minor additions which accelerate the molecular rearrangement (H_2O, alkalies). P. Wulff and S. K. Majumdar found that the addition of small amounts of water to boric oxide glass first increases and after passing through a

maximum decreases the density. The first traces of water exert a "mineralizing" action, decreasing the activation energy of the molecular rearrangement and thus allow the glass to assume a more compacted structure than one free of water. Only if a certain concentration of H_2O is exceeded, the spaciousness of the OH groups containing structures overshadows the "compacting" effect.

Kracek, Morey and Merwin, in their investigation of the system B_2O_3-H_2O, write in the discussion of their results:

> "It should be emphasized that B_2O_3 is a unique substance. In its vitreous form it is tough rather than brittle and this property appears to be carried over into the crystalline form, the scratch hardness of which is certainly below that of steel, but which resists crushing to an extraordinary degree."

We may say today that one of the unique features of this oxide is based on the shape and low symmetry of the planar BO_3 units which make up its structure. This accounts for its lacking tendency to crystallize its apparently unusually high viscosity despite its low melting point and, as will be shown later, for its anomalous temperature coefficient of surface tension.

2. Boric Oxide-Silica Glasses. Boric oxide carries its two features, low melting point and sluggish molecular rearrangement into its mixtures with silica. Its fluxing action has been used in the group of "Pyrex" brand glasses which have a high silica content (80%) and owe their stability towards devitrification to their content of boric oxide. In a study on the devitrification of "Pyrex" glasses, F. Morey remarked that the "Pyrex" glass No. 774 has the lowest liquidus temperature of any known mixtures of so high a silica content.

Its sluggish molecular rearrangement is responsible for the difficulty involved in homogenizing pure B_2O_3-SiO_2 mixtures. Burgess and Holt (1903) as well as Guertler (1904) describe SiO_2 as insoluble in boric oxide. Bleininger and Teetor (1917) heated a number of B_2O_3, SiO_2 mixtures up to 72 mol % SiO_2 and describe the melts as opaque but glassy. Dimbleby, Hodkin, Parkin and Turner (1923) observed two layers, an upper clear, and a lower opaque one, after 48 hours of heating (1400°C) a mixture 50 mol % SiO_2 and 50 mol % B_2O_3. Their analysis of the layers revealed that this phenomenon is not due to immiscibility.

Indeed, J. W. Greig (1927) made some mixtures of B_2O_3 and SiO_2 into homogeneous clear glasses and found no evidence of immiscibility in this system. His findings were confirmed by Cousen and Turner (1928) who made an extensive study of B_2O_3-SiO_2 glasses over a wide range of compositions. The properties of these glasses indicate that the two oxides are mutually soluble and that there are not great deviations from additivity. The densities of B_2O_3-SiO_2 glasses as well as their thermal expansions make it probable, that their structures contain the two units BO_3 triangles and SiO_4 tetrahedra interlinked in a way that each oxygen forms a bridge between either two boron, two silicon or a boron and a silicon atom. Such a structure may be called a true mixture of the two oxides, none of which changes the nature of its unit. This is in agreement with the additivity of properties and stands in striking contrast to the role of B_2O_3 in alkali borate and alkali borosilicate glasses. This picture is in agreement with the results of Biscoe, Robinson and Warren (1939) who studied the atomic structure of four B_2O_3-SiO_2 glasses containing 15, 30, 45 and 60% SiO_2.

3. The Atomic Structure of Vitreous Alkali Borates. One "unique feature," perhaps the most important one, of boric oxide as a glass former is brought out only in its combination with alkali oxides or silicates. Boric oxide in combination with silica lowers the liquidus temperature of the latter more than any other known addition, but nevertheless, there is nothing unusual about its effect on the properties of B_2O_3-SiO_2 glasses. If, however, boric oxide is added to an alkali, or alkali-lime-silica glass, it exerts an influence which is contrary of that expected from the properties of the pure B_2O_3. As mentioned in the introduction, increasing additions of B_2O_3 to such a glass causes all properties to go through an extreme value either maximum or minimum. This phenomenon, often referred to as the "boric acid anomaly," was not understood before the atomic structure of sodium borate glasses was derived by J. Biscoe and B. E. Warren. Their work revealed a characteristic feature of boric acid; namely, the change from threefold to fourfold coordination of the boron. This phenomenon was later confirmed and more closely examined by R. L. Green, who used the same approach as Biscoe and Warren (Fourier analysis of X-ray diffraction patterns) for elucidating the structure of potassium borates. As there is no other cation known which changes its coordination number from three to four upon the addition of alkali, this is another unique feature of boric oxide and it is probably the most important, from a technical point of view. In order to fully understand and appreciate its meaning it will be necessary to compare the strucural changes occurring in B_2O_3 glass upon the addition of alkali with those taking place in vitreous SiO_2 as revealed through the work of B. E. Warren and J. Biscoe.

The structure of silica glass is governed by two factors: a) The silicon ions are surrounded by four oxygen ions forming the corners of regular tetrahedra. As the cation to oxygen ratio is 1:2, it is necessary that each oxygen ion will tightly bind two silicon ions together; b) No oxygen ions are bound to more than two silicon ions, which means that two SiO_4 tetrahedra have one corner in common, but never an edge (2 oxygens) or a face (three oxygen ions). This factor is important, because it gives the structure a certain flexibility and thus is responsible for the stability of the vitreous silica. The random network of SiO_4 tetrahedra is almost as stable as that of the cristobalite.

Upon addition of alkali, say Na_2O, the structure of a SiO_2 glass undergoes a principal change. The SiO_4 tetrahedra remain the glass-forming units, but the increased oxygen to silicon ratio causes some oxygen ions to belong to only one SiO_4 group rather than two. These "single bonded" oxygens loosen the structure of the glass, decreasing the viscosity and increasing the tendency of the melt to devitrify. The more Na_2O is introduced, the more oxygen bridges between to Si^{4+} are broken, which means that the fraction of oxygen ions tied to only one silicon increases.

Addition of alkali to boric oxide produces the opposite effect. The boric oxide glass consists of BO_3 triangles, but if the oxygen to boron ratio is increased some of the

boron ions assume fourfold coordination. This change from BO_3 triangles to BO_4 tetrahedra strengthens the glass structure and makes it resemble silica. Addition of boric acid to alkali containing glasses therefore increases their chemical resistivity, decreases their thermal expansions and raises their softening ranges.

The Fourier analysis of the X-ray diffraction patterns of simple alkali borates reveals this structural change directly, because it gives us the average coordination of the boron and the boron-oxygen distance.

Table VI contains these values for the alkali borate glasses as determined by Biscoe, Warren and by Green.

TABLE VI.

Glass Composition	B-O Distance	Coordination of B^{3+}
100 mol % B O	1.39 A.U.	3.1
88.6 " " " 11.4 mol % Na_2O	1.37 "	3.2
77.5 " " " 22.5 " " "	1.42 "	3.7
66.7 " " " 33.3 " " "	1.48 "	3.9
92.1 " " " 7.9 " " K_2O	1.40 "	3.1
83.7 " " " 16.3 " " "	1.38 "	3.6
75.6 " " " 24.4 " " "	1.42 "	3.8
66.6 " " " 33.4 " " "	1.45 "	3.9

The X-ray examination proves that addition of alkali to B_2O_3 glass increases the average coordination of boron as well as the boron to oxygen distance. The latter results from the fact that this value is 1.36 for triangular but 1.53 for tetrahedral coordination.

Examination of other properties, especially thermal expansion, reveals that this change from BO_3 to BO_4 groups does not lead to completion but falls off beyond about 16% Na_2O or 22% K_2O. This is not surprising because fourfold coordination is not natural for boron and is assumed only under special conditions. Like other glass forming oxides, such as silica or phosphorus pentoxide, the boric oxide loses its glass forming properties if increasing amounts of basic oxides are added. In the discussion of the binary system Na_2O-B_2O_3 it was mentioned that in contrast to the corresponding silica system, there is no continuous decrease in the tendency of the sodium borates to form glasses, but a distinct gap around the composition of the metaborate $Na_2O \cdot B_2O_3$. This compound has not yet been obtained in vitreous condition,

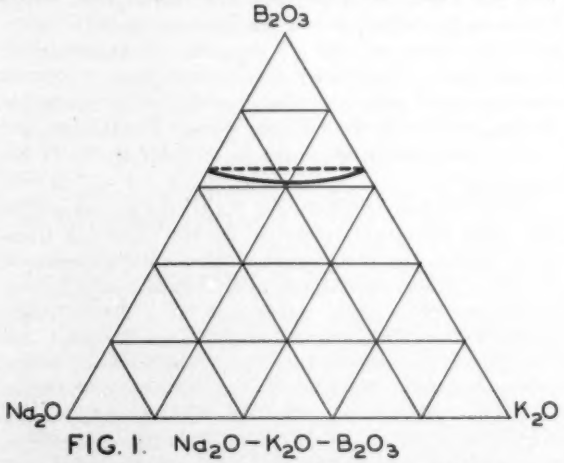

FIG. 1. $Na_2O - K_2O - B_2O_3$

Fig. 1—In the system Na_2O-K_2O-B_2O_3 the field of glass formation is slightly extended to 38.5 mol % alkali, if equal numbers of Na^+ and K^+ ions are used. The use of Na_2O and K_2O increases the area of glass compositions by 15%.

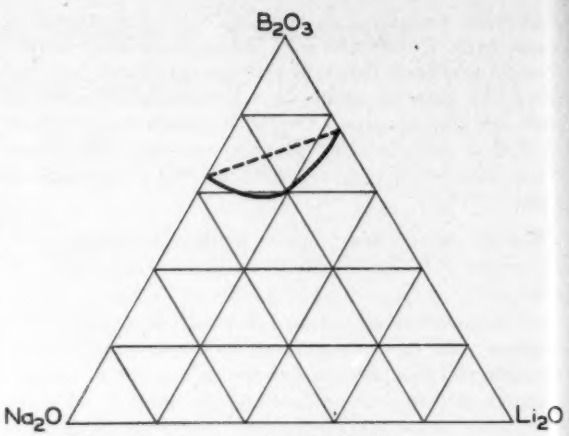

FIG. 2. $Na_2O - Li_2O - B_2O_3$

Fig. 2—In the system Na_2O-Li_2O-B_2O_3 glass formation could be extended to 41 mol % alkali (14.4% Li_2O + 26.5% Na_2O), which means an increase of the area by 50%.

but glasses of both more acidic and more basic compositions are known to form glasses on rapid chilling. The sodium orthoborate $2Na_2O \cdot B_2O_3$ in small quantities can be supercooled to a glass. No exact interpretation of this phenomenon can yet be given because the atomic arrangements of these borates is still unknown. S. B. Hendricks in his paper, "Polymer Chemistry of Silicates, Borates and Phosphates," points out several possibilities of how the different complex anions can be interlinked. He brings out clearly that with certain oxygen:boron ratios there is a greater possibility to polymerize than for others even if one limits the anionic groups to BO_3 units. It is probable, however, that the orthoborate of sodium, having a B:O ratio 1:2.5, will form a glass containing BO_4 tetrahedra.

It is very difficult to compare the glass forming qualities of different mixtures, because one deals here with a property which cannot be accurately defined nor measured. Later, in a discussion of the use of boric acid as a minor constituent we will have to refer to one of its most useful qualities; namely, to enhance glass formation and prevent devitrification. This role of B_2O_3 can be readily understood for SiO_2-B_2O_3 mixtures with only minor additions. According to G. W. Morey, B_2O_3 lowers the liquidus temperature of SiO_2 more than any other oxide. As the liquidus temperature represents the highest temperature at which crystals may form, any constituent which lowers the liquidus temperature will increase the temperature range where devitrification is impossible.

A discussion, however, of the equilibrium conditions of ternary and quaternary systems with B_2O_3 as a constituent will not help us very much. G. W. Morey studied soda-lime-silica glasses by adding increasing amounts of B_2O_3 (up to 5%) to 21 glasses in and near the field of devitrite $Na_2O \cdot 3CaO \cdot 6SiO_2$ and determined the influence on the liquidus temperature and on phase boundaries. He found that in the region of commercial glasses addition of B_2O_3 in small quantities lowers the liquidus temperature and with it the tendency to devitrify. For larger quantities (4-5%) the effect of B_2O_3 on the liquidus temperature can be reversed. In respect to its effect on the liquidus temperature, boric oxide is by no means unique. For certain soda-lime-silica glasses the addition of magnesia would be far more effective than that of boric acid or

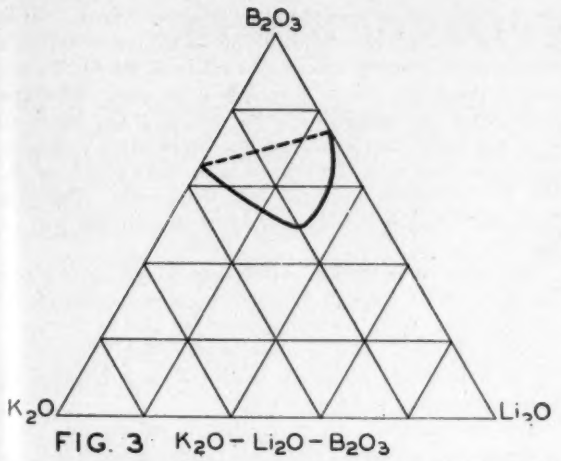

FIG. 3 $K_2O - Li_2O - B_2O_3$

Fig. 3—The combination of the dissimilar K^+ and Li^+ showed the strongest deviation from additivity. In the system Li_2O-K_2O-B_2O_3 glasses could be obtained with 51 mol % if 19.4 mol % Li_2O and 31.6 mol % K_2O were used. This combination of K_2O and Li_2O exactly doubles the area of glass forming compositions.

alumina. Practical experience speaks against these deductions made from phase equilibria studies.

For most purposes glass technologists are not interested in the temperature at which a glass melt may be kept indefinitely with devitrification to occur, but rather in a low rate of crystallization in the working range. In order to do justice to boric oxide as a means to prevent devitrification not only the phase equilibria should be consulted, but the rate of devitrification must be taken into consideration. The observations of G. W. Morey and E. Ingerson, that danburite $CaO \cdot B_2O_3 \cdot 2SiO_2$ could not be synthesized without the application of hydro-thermal methods and that the natural mineral could be easily overheated and kept above its incongruent melting point without decomposition, have probably much more bearing on the role of B_2O_3 in glasses than the phase relationships. So far as their influence upon the rate of crystallization is concerned, there is a distinct parallelism between B_2O_3 and Al_2O_3, but a strong contrast exists between these two oxides and, for example, magnesia.

The effect of B_2O_3 on glass formation is dominated by two factors. BO_3 triangles are highly asymmetrical and despite the relative weak structure of B_2O_3 glass a rearrangement of BO_3 units requires a high energy of activation. BO_4 tetrahedra, on the other hand, are participating in the glass structure by alternating with SiO_4 tetrahedra. Rearrangements are slow because they involve breakage of the major bonds.

The role which the symmetry of glass forming units plays in the ionic rearrangement essential for devitrification is brought out clearly by experiments which A. W. Bastress carried out in our laboratories.

For determining whether or not a borate formed a glass, the following method was adopted:

Mixtures of B_2O_3 and alkali carbonates were melted in a platinum crucible and poured into a graphite mold. Regardless of whether it was crystalline or not it was remelted in a cylindrical platinum crucible having a small hole in its bottom. This crucible was suspended in a vertical furnace so that the melt would drop out onto a rotating graphite table. Each droplet formed a little bead of about 0.3 grams which was then examined under the microscope. If no crystals were detected, the composition was classified as "glass forming."

This method is, of course, arbitrary and does not give the same limits of glass formation as revealed by the quenching technique used for the determination of phase equilibria. It also does not give us the information as to how compositions behave when melted in commercial quantities. But, for comparison, the data obtained were found useful.

For the simple alkali borates the limits of glass formation were found to be at

24 mol % Li_2O
35 mol % Na_2O
35 mol % K_2O

The effect which a combination of two alkalies exerts upon the field of glass formation is of particular interest. If the tendency of the melts to crystallize would depend on the oxygen to boron ratio only, there should be no difference between the different alkalies. Furthermore, the replacement of a part of one alkali by another on a molar basis should not influence the devitrification. This, however, was found not to be true. The dotted lines in the Figures 1 to 3 represent the limits of glass formation as expected from an additive behavior. The full lines give the limits as found experimentally. The area enclosed between the dotted and the full lines correspond, therefore, to the glass composition field gained through the use of two alkalies instead of one.

The combination of dissimilar ions decreases the symmetry around the BO_4 units and thus increases the activation energy of the molecular rearrangement.

4. Characteristic Features of B_2O_3 as a Constituent of Silicate Glasses. The previous chapters describe the atomic structures and some of the properties of B_2O_3-SiO_2 and of alkali borate glasses. For most practical purposes, however, these simple compositions are of little use. The question, therefore, arises as to the effect which the addition of B_2O_3 will have on the properties of a complex silicate glass which leads immediately to the practical aspects of the usefulness of B_2O_3 as a glass constituent. The property of B_2O_3 to lower the melting temperature is shared by other fluxing agents, such as BaO, As_2O_3 and fluorides. The chemical resistivity of a glass can be improved and its tendency to devitrify can be reduced by B_2O_3, but the same can be accomplished by Al_2O_3. Boric oxide was found to decrease the thermal expansion of a glass and make it more resistant to thermal shock. Silica, however, is known to affect the glass properties in exactly the same way. On a glance, boric oxide does not seem to impart properties to a glass which could not be achieved by other additions just as well.

In order to understand the usefulness of boric acid as a constituent of glasses we have to distinguish between structural changes and properties in the high temperature region (melting and fining) and those in the low temperature region, where the glasses are used. Let us discuss this problem on hand of one of the most important properties of boric oxide—its role as a flux. There are several methods to flux a high melting glass. The addition of alkali or CaO increases the oxygen to silicon ratio and thus decreases the number of Si-O-Si bridges per unit volume. The viscosity of a silicate melt is greatly decreased with the number of bridges between SiO_4 tetrahedra.

Another method to weaken the glass structure and in-

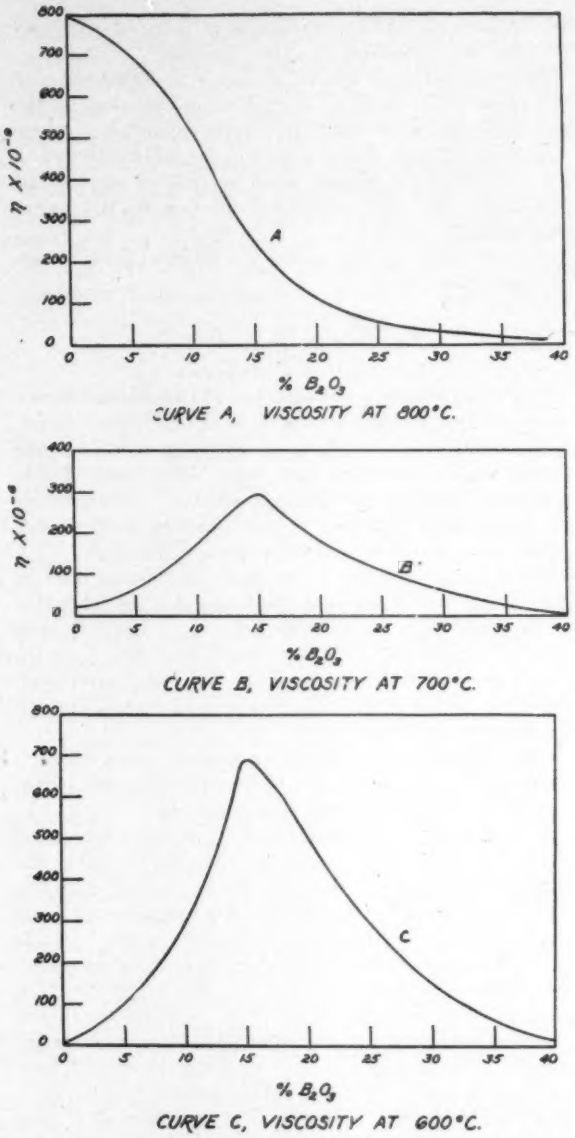

Fig. 4 a, b and c—give the viscosities of a series of glasses having the compositions Na_2O, B_2O_3 (4-X), SiO_2 for 800°C. (a) 700°C. (b) and (c) 600°C. (After S. English)

crease fluidity is the partial replacement of the doubly charged O^{2-} ion by F^- or OH^-, anions of similar size but only half the electric charge of the O^{2-}. This is the way fluorides act as fluxing agents. Normally the amount of OH^- which can be introduced into a glass is not sufficient to make the effort worthwhile. However, in natural silicate melts the water content of a magma is a decisive factor in determining its fluidity.

A third method is the introduction of BO_3 units into a glass instead of SiO_4 groups. As the BO_3 groups consist of triangles having B^{3+} in the center, they cannot impart to the glass structure the same strength as an SiO_4 group the forces of which extend into three dimensions rather than two. In the high temperature region B_2O_3, with its low melting point, imparts meltability to a silicate because it weakens its structure.

On cooling the glass melt the first two changes, namely, increase of oxygen:silicon ratio and replacement of O^{2-} by F^-, continue to keep the glass structure "weak." It is true that through the choice of the alkali ions or through mixtures of different oxides, the effect of the O:Si ratio can be modified, but in principle it persists. Within a wide range of compositions the use of B_2O_3, however, does not result in a weakened low temperature structure, but on cooling a rearrangement takes place which causes the BO_3 triangles to form BO_4 tetrahedra. The BO_4 groups strengthen the glass structure in a similar way as the SiO_4 groups.

The same phenomenon which was found to produce the boric oxide anomaly in alkali borates, the change of coordination, exists for temperature as well as for composition changes. This can best be observed if the mobility of borosilicate glasses is examined as a function of both composition and temperature.

The measurements by S. English bring out this phenomenon very clearly. There is a fundamental difference in the viscosity-temperature curves obtained by the introduction of B_2O_3 and those obtained by CaO or MgO. In the high temperature region, B_2O_3 greatly reduces the viscosity and there exists a proportionality between the fluxing effect and the amount of B_2O_3 introduced. This, however, does not hold true in the low temperature region.

At 800°C. the logarithm of the viscosity decreases steadily if SiO_2 is replaced by B_2O_3 on a molecular basis. The curve is S-shaped but one can expect that at still higher temperature there will exist a nearly linear relationship between fluidity and number of SiO_2 molecules replaced by B_2O_3.

The viscosity values of the same glasses at 700°C. show a maximum viscosity at 15% B_2O_3 which becomes even sharper as the temperature is lowered. This behavior of the temperature viscosity relationship as a function of the composition was explained by S. English as due to the presence of a compound in the low temperature region which decomposes at high temperature. In the modern parlance of structure one tries to avoid the term "compound" for glasses and ionic crystals. The meaning of English's interpretation, however, remains valid. The high viscosity of a sodium boro-silicate glass in the low temperature region is due to the formation of BO_4 groups from the BO_3 triangles which were present at high temperature. The low temperature structure of such a glass containing BO_4 an SiO_4 group resembles that of the mineral danburite, which also consists of a network of BO_3 and SiO_4 tetrahedra. The high temperature structure of such a glass containing BO_3 and SiO_4 units combines the characteristic features of the silicate and of the "uncombined" or "free" boric acid.

In summarizing, we may say that boric oxide as a flux is unique since it weakens the glass structure only in the high temperature region, but does not extend this weakening influence to the low temperature region and to the low temperature properties.

Such a statement is rather general and needs certain restrictions. The main restriction is the composition of the glasses. The statement applies only to those glass compositions where the oxygen to silicon ratio is sufficiently high to make it possible for the BO_3 triangles to change into BO_4 tetrahedra on cooling. In binary glasses of the composition SiO_2-B_2O_3 this condition is not fulfilled. Addition of boric oxide to silica glass weakens its structure in both the high temperature and

(Continued on page 228)

WINTER MEETING OF OPTICAL SOCIETY

Glass was of limited importance in the discussions of the Winter Meeting of the Optical Society which took place in New York on March 4, 5 and 6, 1948. Mr. Harry J. Keegan of the National Bureau of Standards has proposed the use of opal glass standards, machine ground, polished and calibrated against carefully controlled magnesium oxide, for industrial spectrophotometry and colorimetry. Mr. J. Widmyer of the Armstrong Cork Company extrapolated the dominant wave length of amber bottles thinner than test samples from plots of dominant wave length versus thickness obtained with typical amber batches. This paper fits into the small but continuous stream of publications slowly introducing scientific methods into the control of colored glass.

Some of the papers on colorimetry deserve the attention of glass technologists. Mr. E. Richardson of the Eastman Kodak Company improved the detailed techniques of the G.E. Recording Spectrophotometer. The new photoelectric color-difference meter constructed by Dr. R. Hunter, of the Henry A. Gardner Laboratory, found much appreciative comment. In this apparatus photocell windows and measuring circuits have been selected so that three color values are read directly from 10 turn potentiometers. The rheostats may be set to standard values and color differences between standard and specimen may be read directly. The three color values are based on F. Scofield's* isometric scales so that the differences measured are closely related to those evaluated by average observers. While there is a difference between the combinations of the instrument and those theoretically required to duplicate the Standard Observer, the results will generally suffice for exacting industrial practice and can easily be interpreted for more precise requirements. The instrument is limited to reflecting materials. Mr. G. Aklin of Eastman Kodak described the lens systems based on the rare earth glasses of Morey, De Paolis and Eberlin which in the past years have been the greatest progress made in glass chemistry.

Filters may be considered a subject of related interest to glass technologists who watched during the past three years the fascinating progress of the interference method. Dr. F. Turner and Mr. O. Ulrech, of Bausch and Lomb, demonstrated interference filters having wedge shaped spacer films causing the filter to have a linearly continuous wave length variation of transmission. The demonstration of the production of variable, narrow transmission bands with one or two pieces of filter material was spectacular.

Special topics of the meeting were spectroscopic pyrometry and wind tunnel optics. The latter are of considerable present and future significance in aerodynamics. The interferometer, recording wave trains passing through wind tunnel and control chamber, respectively, is expected to compare actual conditions with computations made in devicing cones, wings and wedges moving at supersonic speeds.

The usual sessions were concerned with many aspects of (1) spectrophotometry and colorimetry, (2) general optics, (3) infra-red optics, and (4) spectroscopy. More details on phase microscopy are being developed. The extension of infra-red work continues at a remarkable pace.

For the purpose of brief characterization the following presentations of general interest are arbitrarily selected:

Dr. Mueller, of M.I.T., presented a new theory of optics which was derived without the assumption of the validity of a wave theory. The paper, strangely, received no formal comment which made it difficult for the average audience to react to the stimulating presentation. Drs. S. Duntley and E. Edwards, of M.I.T. and Harvard, respectively, presented diagnostic methods based on the spectrophotometric examination of the skin color. This is, plainly speaking, the scientific form of looking at your complexion. The scientists emphasized, in spite of the suggestive attitude of the audience, that so far they have abstained from cosmetic issues. Dr. Riggs and Dr. Parker, of Brown and Bowdoin universities, penetrated the surface of vision in direct measurements of electropotentials in the illuminated sensitive layer of the eye.

A foreign visitor of distinction, Dr. Scandone, of the Uffizi Galileo, Firenze, Italy, was cordially welcomed by his colleagues and participated in the lively discussions on phase microscopy and other subjects.

Following the lead of the Color Council group in 1947, optical experts submitted to an inquisitive quiz at the dinner at which occasion the presiding officer, Dr. Kingslake, showed to his many friends his skill under unusual circumstances.

INTER-SOCIETY COLOR COUNCIL

The Inter-Society Color Council, which is constituted by the official delegations of national societies and individual members, met in New York on March 2 and 3, 1948.

The color interests of glass technologists are implicitly represented by the delegation appointed annually by the President of the American Ceramic Society. The delegation traditionally includes at least two or three members of the Glass Division. The chairman of the delegation for 1948 is Dr. Richard Hunter, well known as the designer of instruments widely used in the determination of gloss, opacity, reflection and color of ceramic materials.

The meeting heard reports of sub-committees and member societies as well as individual papers on color topics of broad scope.

Glass technologists will be interested in the proceedings of three of these sub-committees. The committee headed by Dr. Dean B. Judd of the National Bureau of Standards, a leading color expert, is revising an official list of well defined color names based on a common vocabulary. Dr. S. Newhall, of Eastman Kodak, and his committee have nearly completed an important dictionary of terms. In this compilation one will find, for instance, the term "brightness"; its definition; a list of technical societies using the term in the sense of this definition; synonymous terms used by other societies; and, other definitions used for the same term by other societies. Anybody who has been puzzled by the very existence of these four possibilities will appreciate the value of this guide. A new subcommittee under Dr. R. H. Osborn, of the Hercules experiment station, will endeavor to express transparent color standards in precise color notations. Such stand-

(Continued on page 227)

*"A Method for Determination of Color Differences." Scientific. Section Circular 664, Nat. Paint, Varnish, Lacquer A.S.J. Washington 1945.

CONVECTION CURRENTS IN A GLASS TANK

By IVAN PEYCHÈS, Sc.D.
Director of Research in the Glass Factories of the *Compagnie de Saint-Gobain*

TRANSLATED FROM THE BULLETIN DE L'INSTITUT DU VERRE (PARIS) FOR JUNE, 1947

By LOIS SUTTON and S. R. SCHOLES

PART IV

B.—*The behavior of glass in the furnace chamber, deduced from the theory.*

a. *Order of magnitude of the phenomena.* In the preceding chapter we have developed a theory of the ideal convection, introducing conditions of uniformity of properties which deviate notably from reality. In the last paragraph, we have indicated in which direction the differences should be introduced. In the present paragraph, we shall, however, show by numerous applications that the orders of magnitude of the calculated phenomena represent reality well enough.

1—*Thickness of the respective incoming and outgoing currents in the unobstructed tank.*—The theory requires in the direct current a thickness of 4/10 of the depth, and we must pay attention, following the conclusions of § f, to a smaller thickness. Experimentally, Novaky, using the floating plungers, has determined the position of the neutral line to be 40 cm. beneath the surface of a normal bath (depth 105). Opperman[23], using the sinking pallets, found 30 cms. In the unobstructed tank the thickness of the direct current is about 1/3 of the depth of the tank.

2—*Speed of the glass in the throat.*—The maximum speed in the throat is given in (11).

Let us adopt, as orders of magnitude, the following hypotheses:

Fall of temperature due to the throat . . $\Delta\theta=\theta_1-\theta_2=150°$
Height of the throat . . . . . $h_0=30$ cm.
Length of the throat . . . . . $h_0=100$ cm.
(the width f, supposedly large, does not enter into the calculation of the speed)
Specific gravity of the glass . . . . . $\rho=2.5$
Acceleration of gravity . . . . . $g=10^3$
Coefficient of expansion . . . . . $k=10^{-4}$
Mean viscosity . . . . . $\eta=300$

These hypotheses bring about: $C=2.10^{-4}$, or: V max.= 0.26 cm/s; that is, about 10 m/hr., which is an entirely acceptable order of magnitude. (Oppermann has measured 20 m/hr. in the neck of a tank; different authors have measured in the throats speeds ranging from 10—20 m/hr.)

3—*Speed of the glass in an unobstructed chamber.*—The unobstructed tank of great length is rarely observable; upon the occasion of a change of barrier in the l'Electroverre-Romont, we have been able, however, to measure superficial speeds of the order of 12—15 m/hr. with a fall of temperature in the axis of the furnace of about 10°/meter.

The expression in (27) would furnish, in this case, for u_0, 65 m/hr., a much higher speed. This is perhaps due to the fact that, on the one hand, the viscosity which can be introduced into the calculation is no longer the *medium* viscosity in a throat ($\eta=300$), but the viscosity at the bottom ($\eta\simeq 1000$), since it is there only that there is zero speed. On the other hand, the furnace presenting the clearest longitudinal convection is the narrow furnace (that of Romont was two meters wide for one meter of depth) where the friction on the lateral walls is not negligible. The lateral friction can be introduced in the calculation and brings about, with $\eta\simeq 10^3$, some speeds of the order of 15 m/s, this time in direct accord with experience.

b. *Several practical conclusions deduced from the theory* (important). Without otherwise attaching importance to the calculation of the above paragraph, we shall draw the following conclusions from the results obtained in the preceding chapter.

Considering unobstructed tanks or tanks cut by barriers or throats, the speed of the convection movements depends *in large proportion,* on the height of the free passage, and depends linearly on the fall of temperature, to obtain: $(\theta_1-\theta_2=\Delta\theta)$. The calculation gives:

$$(33)\quad v=K\Delta\theta h_0^3$$

The quantity of heat carried by convection is considerably influenced by this. The calculation gives:

$$(34)\quad Q=k'\Delta\theta^2 h_0^4$$

It is not necessary to make the hasty conclusion that when a barrier is worn out the speed must vary considerably; indeed, the only magnitude imposed, that which is the first cause of convection movements, is the quantity of heat to be transported *to compensate the losses* of the non-heated portion. The latter can be considered as constant in a given furnace.

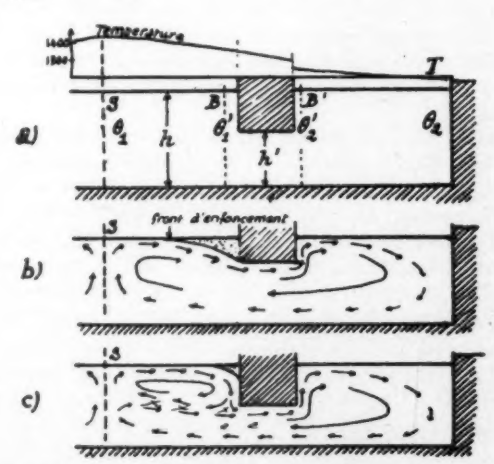

Fig. 30. front d' enfoncement = sinking front.

[23]Cited by Allolio R. Fachausschussber (DGG, 30, 1934, 3rd part).

The constant losses $\Delta\theta$ and h_0 are not independent; they are tied by the relation:

$$(35) \quad \Delta\theta = \frac{k}{h_0^2}$$

If a barrier of 40 cms. wears down by 10 cms., the free height passing from 60 to 70 cms., the fall of temperature is no more than 3/4 what it was before. The glass is too hot at the machine.

The speed of the superficial current is increased, but only following the proportion $v = k^1 \cdot h_0$, and is increased by 1/6.

The glass being too hot at the machine, there is a temptation to recool it by de-heating, that is to say by increasing the losses, and consequently, Q. There an unsatisfactory operation is seen. Since $\Delta\theta$ is proportional to $\sqrt{Q}$, it is necessary to quadruple the losses in order to obtain a double fall of temperature that is due to the parallel increase of the convection speed. In the preceding concrete case, in order to regain the quarter lost in the fall of temperature, it is necessary to increase the losses of the cold compartment by half.

This case is frequently found in the glass factory. To have glass at the working temperature it is necessary to lengthen the furnace. But, in lengthening it, one also increases the speed of the current which carries the heat in such a manner that it is necessary to *lengthen the furnace to a great extent* in order to have a *small degree of cooling*. The production is lowered, but in compensation the more intense currents produce glass of greater homogeneity. We can thus draw the following conclusion:

The long furnace is a furnace of low production but of higher quality.

Experience confirms this prognostication.

But, it is equally possible to lower the working temperature by checking the convection, and it has been observed that it is especially the *height* of the passage connecting the two compartments which is the important point. The *throat* carries out its role of checking very well and leads to thick-set and economical furnaces. Unfortunately, the quality of the glass shows itself here much more because the "shift" at the throat, being almost at a point, the trajectories of the surface glass are radiating and the isotherm is concave and centered on the throat. Each gathering point receives "its" particular glass, which can be sufficiently homogeneous to form a parison, but in no case would it contribute to the formation of a layer sufficiently homogeneous for making flat glass.

These considerations have led us to investigate a way of efficaciously checking the convection by leaving a very large passage of glass in order to avoid the local shift. This way is a *crevice* of low height occupying all the width, or an appreciable part of the width, of the furnace. As we shall show that the isotherm which exists on the surface after a barrier is that which corresponds in height to the ceiling of the free passage, the crevice will be placed on the isotherm of the fusion compartment which is desired in the following chamber. Some furnaces have been constructed on this principle and give excellent results from the point of view of quality as well as economy. (See the last plate of this work.)

We have developed this example among many others to show only what a guide the possession of a theory of phenomena can be. In the following paragraph, we shall now give an explanation of the apparent contradictions raised by certain authors.

c. *Dissociation of thermal currents.* Let us now consider (Figure 30-a) a tank from its point source S, that is to say, its hottest point, to its working chamber. The temperature is not uniform from S to B, any more than B′ to T.

From the point source to the barrier, the thermal currents must compensate the losses of this portion of the tank. Now we have the case of an unobstructed tank, and primary currents have the tendency to become established in this portion of the tank, currents conditioned by $\theta_1 - \theta'_1$, and by h.

The current of the throat is conditioned by the heat which it carries into the working chamber to compensate the losses. This flow does not need to be equal to that of the primary current, but if certain conditions of throat dimensions, in accord with the dimensions of the fusion tank, are realized, the primary current passes entirely in the throat, and there is a simple cyclical movement such as that represented in Figure 30-b. The primary sinks in order to pass under the barrier and leaves a stagnant zone. The *sinking front* is the line more or less well defined following which the current sinks. It reappears behind the barrier after having risen almost vertically. The position of the sinking front permits us to draw curious conclusions farther on, concerning the use of multiple barriers.

In most cases, there is incompatibility between the needs of the fusion compartment and those of the working compartment, and there is then *dissociation* of the primary current and the throat current (Figure 30-c). A superficial independent circulation is produced which involves only the layer making contact with the barrier. This circulation is conditioned by the form of the unobstructed tank with a supposed depth $h - h^1$. The neck current is always tied to the height h^1 of the throat, but the effective length is greater than the actual length of the throat.

It seems, *a priori*, that there is interest in favoring the dissociation of the primary current and the neck current, the surface faults (bubbles, infusions), thus having much less chance to pass the barrier, and being driven back, in the superficial portion, towards the hotter zones.

We shall return again to this complexity of phenomena and to the variety which they can take according to the type of furnace observed. From this is easily understood the variety of statements of authors who have studied convection currents:

Hausner[24] has seen only the superficial current and assumes that the bottom current can only be direct and due to the pull. This led, in addition, to the proposal of a furnace in its most logical sense*, in which charging is done opposite the throat.

Flint and Lyle[25] have strongly insisted on the superficial current which they attributed also to the impossibility of a light glass (because it is hot and bubbly) mixing with the cold glass of the depth. Preston (loc. cit.) has studied the influence of these factors. Schild has perfectly represented the "running case" with the side stream of the primary current towards the neck current. It is this that we have retained as the typical case in the preceding part. *(Continued on page 224)*

[24] Hausner, H., *Glastechn. Ber.* 11, 1933, pp. 242-248.
*German patent 529,734.
[25] Flint, F. C., and Lyle, A. K., Journ. Amer. Soc. 15, 8, 1932, pp. 410-418.

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Glass Compositions

Optical Glass. Patent No. 2,434,281. This patent was assigned to American Optical Company by Harold R. Moulton of Southbridge, Mass.

Prior to this invention it has been usual to weigh the ingredients of a glass batch and mix them as thoroughly as possible by mechanical means. As some of the batch was in grains of fairly large size, this method was not always succcessful. This invention overcomes this difficulty by the intimate essential molecular combination of the essential ingredients by which the chemical reactions have taken place prior to melting. This makes unnecessary the operations of stirring and fining.

Four examples of methods of carrying out this invention are given, the first being as follows: If a glass is to be made having the following chemical analysis as used in the prior art—

	Parts by weight
P_2O_5 (phosphoric anhydride)	70
Al_2O_3 (aluminum oxide)	15
BaO (barium oxide)	5
Na_2O (sodium oxide)	10

Then the batch would probably be:

	Parts by weight
75% H_3PO_4 (orthophosphoric acid)	1290
Al $(OH)_3$ (hydrated alumina)	229
$BaCO_3$ (barium carbonate)	64½
Na_2CO_3 (sodium carbonate)	171

Mechanical mixing of these ingredients would offer serious difficulties.

According to this invention, the H_3PO_4 (phosphoric acid) is added to an aluminum compound such as $Al(OH)_3$. A certain amount of barium compound is added to this. The resulting material is evaporated, filtered, washed and dried if necessary. This may then be fed to the melting pot, with or without cullet. Other ingredients may be added if desired provided that they do not affect the chemical combination. This method produces a glass which can be melted at lower temperatures than usual and which has desirable working characteristics.

The following references are of record in the file of this patent: United States Patents: 2,065,502, Bausch, Dec. 29, 1936; 2,241,249, Eberlin et al., May 6, 1941; 339,525, Burgess et al., Apr. 6, 1886; 1,933,739, Kraver, Nov. 7, 1933; 2,215,209, Cornetts, Sept. 17, 1940; 295,410, Knaffl, Mar. 18, 1884; 2,326,059, Nordberg, Aug. 3, 1943; and 1,736,642, Beandry, Nov. 19, 1929. Foreign Patents: 7,281, Great Britain, Aug. 3, 1943, and 360,342, Germany, 1922.

American Optical Company Silica Glass. Patent No. 2,434,303. This patent is the invention of Woldemar A. Weyl of State College, Pa., who assigned it to the above company. In general, the patent proposes a more positive method of controlling the silica content of phosphate and borate glasses.

Silica in the form of quartz sand, as used in the batch, may produce scum upon melting which is undesirable. It has been believed that silica and boric oxide were immiscible but they are if treated for a long time at high temperatures. This patent proposes to alter the silica so that it may be more readily dissolved, by breaking down the O-Si-O-Si linkages and causing the silica to be introduced in a form which does not contain three dimensional bonds. As a general statement, silicates having the formula $RnSiO_3$ or Rn S O_4 may be used.

The gist of the invention is set forth in Claim 1 as follows: In the process of forming a phosphate glass batch containing silica the step comprising initially chemically combining all the silica with at least one of the major basic oxides included in the formula, and adding the silicates so formed to the batch.

The following references are of record in the file of this patent: United States Patents: Re. 15,727, Crossley, Dec. 4, 1923; 51,343, Napier et al., Dec. 5, 1865; 52,917, Washburn, Feb. 27, 1866; 285,436, Shepard, Sept. 25, 1883; 494,636, Jensen et al., Apr. 4, 1893; 522,001, Hyling, June 26, 1894; 1,394,973, Crossley, Oct. 25, 1921; 1,489,026, d'Adrian, Apr. 1, 1924; 1,522,697, Parsons, Jan. 13, 1925; 1,694,831, Rothe et al., Dec. 11, 1928; 2,091,691, Scholes, Aug. 31 1937; 309,741, Rosenzi, Dec. 23, 1884; and 1,091,678, Locke, Mar. 31, 1914. Foreign Patents: 2,537, Great Britain, 1855.

Superopaque Enamel. Patent No. 2,436,825. This patent was assigned to The Titanium Alloy Manufacturing Company of New York by Harold D. Prior of Plainfield, N. J. The patent relates particularly to a superopaque enamel of the zirconium type which contains a relatively large proportion of lithium oxide and phosphorous pentoxide.

While the use of zirconium dioxide has been known for some time, it is quite lately that zirconia has been accepted as an opacifier. Recent experience has shown that this material has very desirable qualities as an opacifier. However, such enamels were subject to attack by fruit acids which objection is overcome by this invention. The following table gives the general frit composition in accordance with the patent:

	Per cent
Na_2O	3-6
K_2O	1-5
Li_2O	3-5
BaO	1-3
CaO	1-5
ZnO	5-7
B_2O_3	7-9
Al_2O_3	20-25
P_2O_5	22-25
SiO_2	7-15
F_2	3-5
ZrO_2	6-10

Raw batches were prepared in accordance with the next following table and smelted at a temperature of from 2250°F. to 2450°F. for a period of from 30 to 90 minutes, after which the batch was treated in the usual way.

RAW BATCHES

	Amblygonite	Milled Zircon	Deh. Borax	K_2CO_3 $1\frac{1}{2}$ H_2O	Quartz	Alum. Hydrate	Zinc Oxide	Milled Limestone	Soda Nitre	Barium Carbonate	ZrO_2 Milled	Soda Ash	K. Spar
A	44.55	9.25	11.09	6.05	7.58	5.90	6.01	7.15	2.42	...	...	...	...
B	42.67	13.27	10.63	1.92	4.17	9.57	5.76	6.83	2.34	2.85	...	...	...
C	42.79	...	10.66	5.80	10.39	9.62	5.77	6.86	2.34	...	5.77	...	...
D	41.98	...	10.46	5.69	10.19	11.33	5.66	6.73	2.30	...	5.66	...	...
E	43.63	...	10.87	5.92	10.58	5.89	5.89	6.99	2.38	...	7.85	...	...
F	43.23	...	10.77	1.95	10.50	9.72	5.83	6.93	2.36	2.88	5.83	...	...
G	47.03	...	9.93	1.54	11.72	10.62	5.34	2.72	2.09	1.96	5.74	1.31	...
H	43.10	11.92	10.74	5.84	6.29	9.69	5.82	6.60	...	...	...	...	...
I	43.84	12.13	10.92	3.39	...	6.92	5.91	7.03	...	...	...	...	9.86
J	45.33	12.58	10.64	1.58	2.45	10.20	5.72	4.37	2.24	2.10	...	2.80	...

The patent is summarized in Claim 1 as follows: 1. A composition suitable for vitreous enamels comprising 3-6% Na_2O, 1-5% K_2O, 3-5% Li_2O, 1-3% BaO, 1-5% CaO, 5-7% ZnO, 7-9% B_2O_3, 20-25% Al_2O_3, 22-25% P_2O_5, 7-15% SiO_2, 3-5% F_2 and 6-10% ZrO_2.

Miscellaneous Processes

Method of Making Glass Beads. Fig. 1. Patent No. 2,436,819. This method was invented by Samuel W. Neidorf of Nutley, N. J., who assigned it to Federal Telephone and Radio Corporation. In sealing wires into the glass envelopes of electronic discharge devices, glass beads are used and the success of the operation depends upon the uniformity in size and quality of the glass from which the beads are made. Beads may be cut individually from tube but this is a slow process and the beads may be imperfect.

The method of this invention produces beads of uniform size and free from chipped or cracked edges. This is done by cementing a bundle of glass tubes together, cutting slices from the bundle and then removing the cementitious material to free the individual beads.

In Fig. 1 a section is shown through a container 1 which is preferably made of glass, filled with glass tubes 2 which are cemented together and held from vibration and relative movement by a cementitious material 3 such as what is known to the trade as "Carbowax". Slices of the desired thickness are then cut off from the bundle by an abrasive wheel. The use of water as a coolant for the cutting wheel is recommended when "Carbowax" is used as a cement as the water has a slight dissolving action on the "Carbowax" particles which adhere to the cutting wheel.

The cementitious material is then removed from the cut slices by soaking them in water which leaves the beads clean and ready for use. Other kinds of cement may be used in which case some suitable solvent should be used to remove it.

The following references are of record in the file of this patent: United States Patents: 2,063,236, Eisler, Dec. 8, 1936; 450,507, Dalot, April 141,891; 2,328,302, Simison, Aug. 31, 1943; and 1,349,955, Harwood, Aug. 17, 1920.

Kent-Owens Stacker. Fig. 2. Patent No. 2,437,214. This invention was made by Albert F. Tremblay who assigned it to Kent-Owens Machine Company of Toledo, Ohio. It is said that this stacker or lehr feeder injurs the bottles or other glassware much less than previous devices.

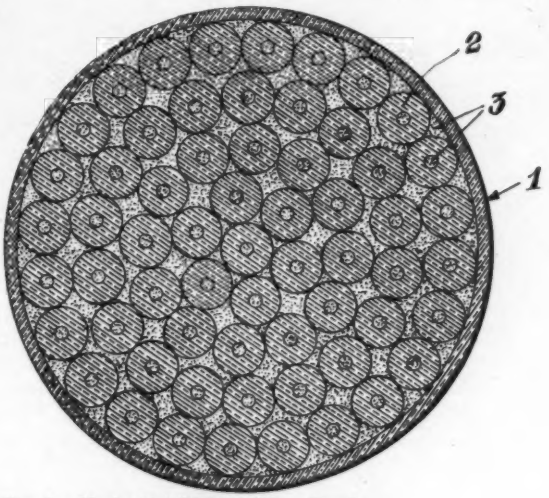

Fig. 1. Method of Making Glass Beads.

The device includes an endless universal conveyor 10 running across the end of a lehr 11 having the usual conveyor belt 12. The ware is pushed off from the conveyor 10 by a wiper 15 on to a vibrating plate 13 having a hinged lip 14 which rests on the lehr belt 12. The conveyor 10 may be as shown in Patent No. 1,424,850

(Continued on page 229)

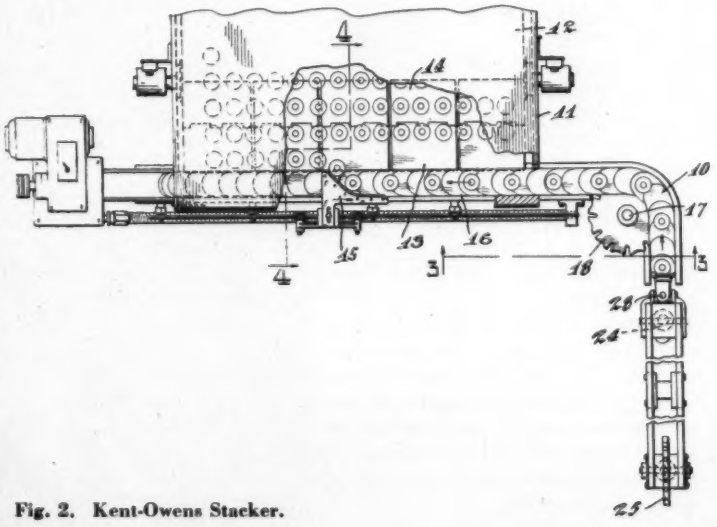

Fig. 2. Kent-Owens Stacker.

Research Digest

Some Experiments on Crystal Growth and Solution in Glasses

If a silicate glass is heated for a suitable time in a certain critical temperature range appropriate to that glass, crystals will be formed (devitrification). The factors influencing the rate of growth of such crystals are of commercial as well as academic interest. Howard R. Swift (*Journal of the American Ceramic Society*, June 1947) reports the results of a study on methods of measuring such crystal growth, experiments on surface devitrification and diffusion experiments.

In measuring the rate of crystal growth at temperatures significantly below the liquidus temperature, Swift used a procedure somewhat similar to that developed by Dietzel. Fragments of twice-homogenized glass, about ⅜ in. in diameter, were placed on a flat piece of platinum-rhodium foil and heated in a uniform temperature region of a Globar electric furnace at various temperatures (750° to 1000°C) for varying lengths of time (1 to 64 hours). The samples were removed from the furnace, air cooled and sectioned vertically through the middle of the specimen. The maximum crystal lengths were then determined microscopically by using a micrometer ocular. For measurements of rates of crystal growth near the liquidus temperature and of crystal solution at temperatures greater than the liquidus temperature, the following procedure was used: a sample of glass (approximately 0.04 gm.) was placed in a special sample holder which in turn was placed in a platinum-wound tube furnace having three heat zones. By suitable location of the sample in this furnace, either crystallization or solution of the crystals could be induced.

By the use of these two methods, a series of measurements were made on both the rate of crystal growth and the rate of crystal solution in a soda-lime glass having a percentage composition of 17 Na_2O, 12 CaO, 2 Al_2O_3 and 69 SiO_2. The most striking features of the data obtained was a) the constancy of the rate of crystal growth until the crystallization zones from opposite surfaces meet and b) the fact that the crystal growth is continuous with crystal solution as the temperature is raised above the liquidus temperature.

To ascertain the effect of dust in the air on surface devitrification, two experiments were made; in the first, filtered air was allowed to pass over the glass sample, while in the second, the air was not filtered. In the first case, the freshly exposed surface of the sample showed little devitrification as compared with the rest of the sample. The second sample, which was devitrified in an atmosphere containing dust (no filter used) showed extensive devitrification even on the freshly exposed surfaces. Since alkali losses, adsorption of water vapor and speed of attainment of optimum temperatures of crystallization would be practically the same in these two experiments, with and without the air filters present, it seemed quite logical to assume that the material which the filters kept out played a large part in the degree of surface devitrification that occurred.

It was the purpose of the second phase of this investigation to explore possible methods of measuring diffusion rates of glasses of similar composition in view of the importance of diffusion to the crystallization of viscous liquids. Accordingly, two glasses were selected from the potash-lime-silica which would not devitrify at 930°C, but when inter-diffused would form such a composition that crystals of $4K_2O \cdot CaO \cdot 10\ SiO_2$ would be precipitated, the meeting point of this compound being 946°C. Samples of these glasses were made and slugs of each were placed in a platinum boat, in such a position that allowed the ends of the two slugs to meet. The boat was placed in an electric furnace at 930°C. and held there for 32 hours. A microscopic examination of the interface between the two glasses revealed that crystals were formed which were presumed to be $4K_2O \cdot CaO \cdot 10\ SiO_2$. A very thin layer of crystalline material was observed at the end of the heat-treating period. This result was surprising and could have been due to: a) the slow rate of diffusion at the temperature used (1.2. 930°C) or to b) the action of the formed crystalline zone as a hindrance to further diffusion.

(Editor's Note): In certain methods of glass fabrication and with certain glass compositions (the method of fabrication remaining constant), the problem of crystallization (devitrification) is of extreme importance. The two methods that the author outlines are easily adapted to most glass plant laboratories, if a microscope is available. Once the time-temperature-devitrification relationship is established, troubles due to devitrification stones or cords resulting from solution of devitrification crystals should be under control.

Effect of Magnesia and Alumina on Rate of Crystal Growth in Some Soda-Lime-Silica Glasses

H. R. Swift (*Journal of the American Ceramic Society*, June 1947), using the methods described in the previous digest, also reports the results of a series of measurements on the rate of crystal growth in a series of glasses having the base composition 74% SiO_2, 16% Na_2O and 10% CaO and MgO, the MgO replacing the lime in 2% steps; and in a series of glasses with 17% Na_2O, 12% CaO and 71% SiO_2 and Al_2O_3, the alumina replacing the silica in 2% steps up to 8% Al_2O_3. A study was also made of the rate of crystal solution in the series with variable alumina. The results were explained qualitatively by considering the viscosity and crystallization temperature changes of the glasses as the composition varied.

From the results obtained, it was concluded that the substitution of magnesia for lime in the soda-lime-silica glass studied decreases the maximum rate of crystal growth for both the primary phase, cristobalite (SiO_2), and the secondary phase, devitrite ($Na_2O \cdot 3\ CaO \cdot 6\ SiO_2$), until the composition with the minimum liquidus is obtained. The maximum rates of growth of diopside ($CaO \cdot MgO \cdot 2\ SiO_2$) and $Na_2O \cdot 2\ MgO \cdot 6\ SiO_2$ increase with

(Continued on page 214)

Photo courtesy Becton, Dickison Co.

HF *hydrofluoric acid*

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Photo courtesy Cambridge Glass Co.

Photo courtesy Cambridge Glass Co.

OTHER
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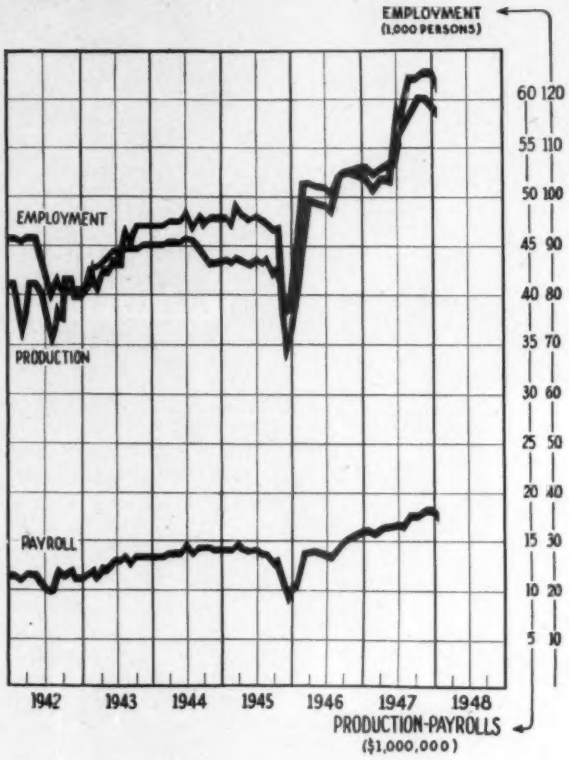
for the glass industry

Ammonium Bifluoride
Aluminum Hydrate Ferric Chloride
Kryolith (Natural Greenland Cryolite)
Muriatic, Nitric, Sulfuric Acids
Salt Cake

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX



According to the Production Index, activity in the glass industry fell off more than 4½ per cent for the first month of 1948. The figure indicated was an estimated $61,700,000, as compared with $64,750,000 shown for December 1947. Production during January 1947 was an approximated $57,000,000, which is about 8 per cent below January this year.

Employment and payrolls: An approximate 2 per cent decrease marked the difference in employment between was 119,700 employed persons as against 117,200 em- December 1947 and January 1948. The December figure ployed persons for January. During January 1947, the number of persons employed was 104,000.

Glass container production for February 1948, based on figures released by the Bureau of Census, continued its downward trend of the past several months falling off close to 8 per cent for the month. The February production figure is 7,335,393 gross, as compared with 8,055,842 gross produced during January. Glass container production during February 1947 was 9,269,161 gross, which is about 20 per cent above February this year. Total glass container production for the first two months of 1948 is 15,391,235 gross, which is a little more than 24 per cent below the 20,424,138 gross produced during the first two months of 1947.

Shipments of glass containers made during February 1948 dropped about 2 per cent from the 7,417,507 gross shipped during January. February shipments were 7,197,-491 gross. Shipments during February 1947 were 8,859,-933 gross, or about 18 per cent above shipments for February 1947. Total shipments made during the first two months of 1948 were 14,614,998 gross, or about 25 per cent below the 19,510,799 gross shipped during the corresponding period in 1947.

Stocks on hand at the close of February 1948 continued to increase and were 8,511,015 gross. At the close of January 1948, stocks were 8,414,716 gross. The stocks-on-hand figure for February 1947 was 4,544,565 gross, which is close to 90 per cent below stocks for February 1948.

(Continued on page 214)

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in gross)

		Production February 1948	*Stocks February 1948*
Foods; Medicinal & Health Supplies; Chemicals, Household, Industrials; Toiletries and Cosmetics	Narrow Neck	2,277,143	2,802,291
	Wide Mouth	1,988,854	2,074,434
Dairy Products		281,251	288,368
Home Canning		130,358	809,286
Beverages, Returnable		757,002	865,658
Beverages, Non-returnable		.....	.....
Beer, Returnable		853,500	801,488
Beer, Non-returnable		143,009	260,893
Liquors		539,087	330,374
Wines		272,941	215,736
Packers' Tumblers		92,248	62,487
Total		7,335,393	8,511,015

GLASS CONTAINER SHIPMENTS

(All figures in gross)

Narrow Neck Containers	*February 1948*
Foods	551,136
Medicinal & Health Supplies	923,229
Chemical, Household & Industrials	448,400
Beverages, Returnable	633,061
Beverages, Non-returnable	.....
Beer, Returnable	636,303
Beer, Non-returnable	146,238
Liquors	550,378
Wines	232,444
Toiletries & Cosmetics	382,312
Sub-Total (Narrow)	4,503,501
Wide Mouth Containers	
Foods	1,660,597
Dairy Products	244,260
Home Canning	*39,083
Medicinal & Health Supplies	182,417
Chemical, Household & Industrials	56,827
Toiletries & Cosmetics	89,366
Packers' Tumblers	107,811
Sub-Total (Wide)	2,380,361
Total Domestic	6,883,862
Export Shipments	313,629
Total Shipments	7,197,491

*This figure represents Fruit Jars only.

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CURRENT STATISTICS . . .
(Continued from page 212)

Plate glass production for the month of February 1948, according to the Hughes Statistical Bureau, was 21,751,195 sq. ft., which is only slightly lower than the 21,957,561 sq. ft. produced during the preceding month. Production during February 1947 was 20,267,537 sq. ft., which is about 7 per cent below February this year. Total plate glass production thus far in 1948 is 43,708,756 sq. ft. in comparison with 42,247,151 sq. ft. produced during the first two months of 1947. This year's figure indicates an increase of 3 per cent above 1947.

Automatic tumbler production for the month of February 1948 fell off close to 5 per cent from the 4,538,969 dozens produced during January. February production was 4,325,496 dozens. Production during February 1947 was 4,834,577 dozens. Shipments during February 1948 were 4,295,901 dozens, which represents a decrease of close to 3 per cent from the 4,415,657 dozens shipped during January. Shipments during February 1947 were 4,735,849 dozens. Stocks on hand at the close of February 1948 were 8,741,301 dozens, as compared with 8,690,020 dozens on hand at the close of January 1948 and 6,478,417 dozens at the close of February 1947.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware for the month of February 1948 were 3,051,054 dozens, which is about 4½ per cent below the previous month's sales of 3,195,459 dozens. Sales for February 1947 were 2,667,998 dozens. Manufacturers' sales for the 12-month period ending February 1948 have reached a total of 41,445,087 dozens, as compared with 45,208,488 dozens sold during the corresponding period of the previous year.

RESEARCH DIGEST . . .
(Continued from page 210)

further substitutions of magnesia for lime.

In the case of the alumina-containing series of glasses, it was concluded that the substitution of alumina for silica decreases the maximum rate of crystal growth for devitrite ($Na_2O \cdot 3\ CaO \cdot 6\ SiO_2$). The maximum rate of growth of Wollastonite ($CaO \cdot SiO_2$) is at first unchanged by the substitution of alumina for silica, but later increases.

DIAMOND ALKALI MOVES HEADQUARTERS TO CLEVELAND

Diamond Alkali Company has announced the removal of its executive headquarters, formerly located in Pittsburgh, Pa., to the Union Commerce Building in Cleveland, Ohio.

According to Raymond E. Evans, President, it is felt that Cleveland provides a more central location for integrated control of the company and its expanding operations, as illustrated by the fact that the main plant is located at nearby Painesville, Ohio, and the further fact that Cleveland is the midpoint in travel time from six of the company's plants in the area between Chicago and the East Coast.

When Production Depends on Product Movement

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NEW EQUIPMENT AND SUPPLIES

DIAMOND BAND SAWING MACHINE

The DoAll Company, Des Plaines, Illinois, has developed a Diamond Band Sawing Machine initiating a new process for cutting hard metal and vitreous material. It employs a diamond saw band, flushing coolant and a precision DoAll band sawing machine.

The machine has a 16″ throat and 10″ work thickness capacity. It provides a rigid smooth 24″ square box-type work table, tiltable 45° to the right, 10° to the left, front and rear fitted with splash guards. A coolant pump, coolant reservoir and drain troughs are provided. The machine is also equipped with one set of special saw guides and blade wipers. It is furnished with a 2 HP drive motor, operating on standard 220/440 voltage, 50/60 cycle current. The machine has a variable Speedmaster drive mechanism to deliver stepless cutting speeds of 3,000 to 8,000 FPM, which is shown on a tachometer-type speed indicator. The blade is completely guarded to the point of work.

A number of specimens of glass, such as hard optical glass supplied by a movie camera manufacturer, have been cut up to a four-inch work thickness on a four-inch radius. Softer glass, such as used in church windows and other architectural purposes, has been contour sawed up to eight inches in thickness. Cutting rates have been over three square inches per minute.

In the realm of hard composite materials, the Diamond Saw Band cut a 1½ inch thick laminated glass fabric piece, which was tightly compressed with a hard thermo-setting binder, at a rate of five square inches per minute.

BRYANT GAS BURNER FOR IMMERSION HEATING

The Industrial Division of Bryant Heater Company, 1020 London Road, Cleveland 10, Ohio, has announced a newly-engineered immersion heating burner assembly.

The assemblies involve scientifically-designed spacer cages which insure the entrainment of the required amounts of secondary combustion air in gas-firing immersed tubes for heating water, oils and other liquid solutions.

The coil cages are furnished separately, or in ready-for-installation assemblies, complete with mixers and associated equipment. The atmospheric type coil cage burner comprises a gas cock, low pressure injector, flame-retaining burner nozzle and coil cage with pilot. Usable with gases having btu. contents of from 450 to 3200 btu., at pressures from 3″ W.C. to 12″, the atmospheric burners are rates from 27,500 to 350,000 btu. per hour. Coil pipe sizes from 1½″ D. to 6″ D. are accommodated.

The blast type coil cage assemblies permit higher capacities by utilizing combustion air under pressure. These units involve a zero governor for controlling gas supply and a pressure type mixer. A centrifugal blower for pressure air can be supplied as an element of the packaged assembly if required. Using air at 4 oz., 8 oz. or 16 oz. pressure, the blast assemblies deliver up to 1,400,000 btu. per hour.

DILLON INDUSTRIAL SCALE

W. C. Dillon & Company, Inc., 5410 West Harrison Street, Chicago 44, Illinois, has announced a new scale designed for high capacity weighing and embodying an entirely new principle of operation.

The new scale with a dial measuring 15″ gives instantaneous readings the moment loads are suspended or lifted. It indicates the true weight of any object and can be supplied in a top range of 0-10,000 pounds. Each scale is carefully checked and must meet an accuracy test of 1% or better or be rejected.

The Dillon Industrial Scale operates upon the scientific principle of the bending of a beam from a true straight line. Its extreme accuracy is due to the fact that the "beam" is held to a tolerance of one-thousandth of an inch. All parts are carefully jig-bored and line-reamed for uniformity.

LEAK DETECTOR

Vacuum-Electronic Engineering Co., 316 Thirty-Seventh Street, Brooklyn, New York, is producing a new leak detection device for industrial applications.

The Veeco Mass Spectrometer Leak Detector, manufactured under license of the University of Minnesota, was developed for special war projects and is now offered to various industries for applications wherever a vacuum, fixed pressure or special atmosphere must be maintained in equipment for extended periods of time, or for insuring leak-protection of many manufactured items.

Applications include testing of varied types of equipment such as glass-to-metal seals, welds, hermetically sealed systems, high-vacuum and pressure systems, distillation equipment, chemical process equipment, ceramics, etc.

ELECTRIC LABORATORY OVENS

Modern Electric Laboratory, 6131 S. Wentworth Avenue, Chicago, Illinois, has announced a new heating, baking and drying oven made of polished steel. Their chief use is for laboratories in conducting various tests with glass products, ceramics vitreous enamel, optical goods and for applications where heat of a precisely controlled nature is required.

Uniform temperature is secured from the heavy nichrome element which covers the entire bottom area. All six sides are insulated with Therm-O-Flake bonded block. The inside dimensions of the ovens are 8″ high, 8″ deep, 8″ wide, in the 500-watt size; 12″ high, 12″ deep, 12″ wide in the 800-watt size; and 14¾″ high, 17¾″ deep, 19″ wide in the 1750-watt size.

All models have a hydraulic electric thermostat that is fully approved by the Underwriters' Laboratories. It has a response sensitivity of ±½°C. Two pilot lights, one a red light, is on when the oven is operating; a green light indicates the proper operation of the thermostat.

CATALOGUES RECEIVED

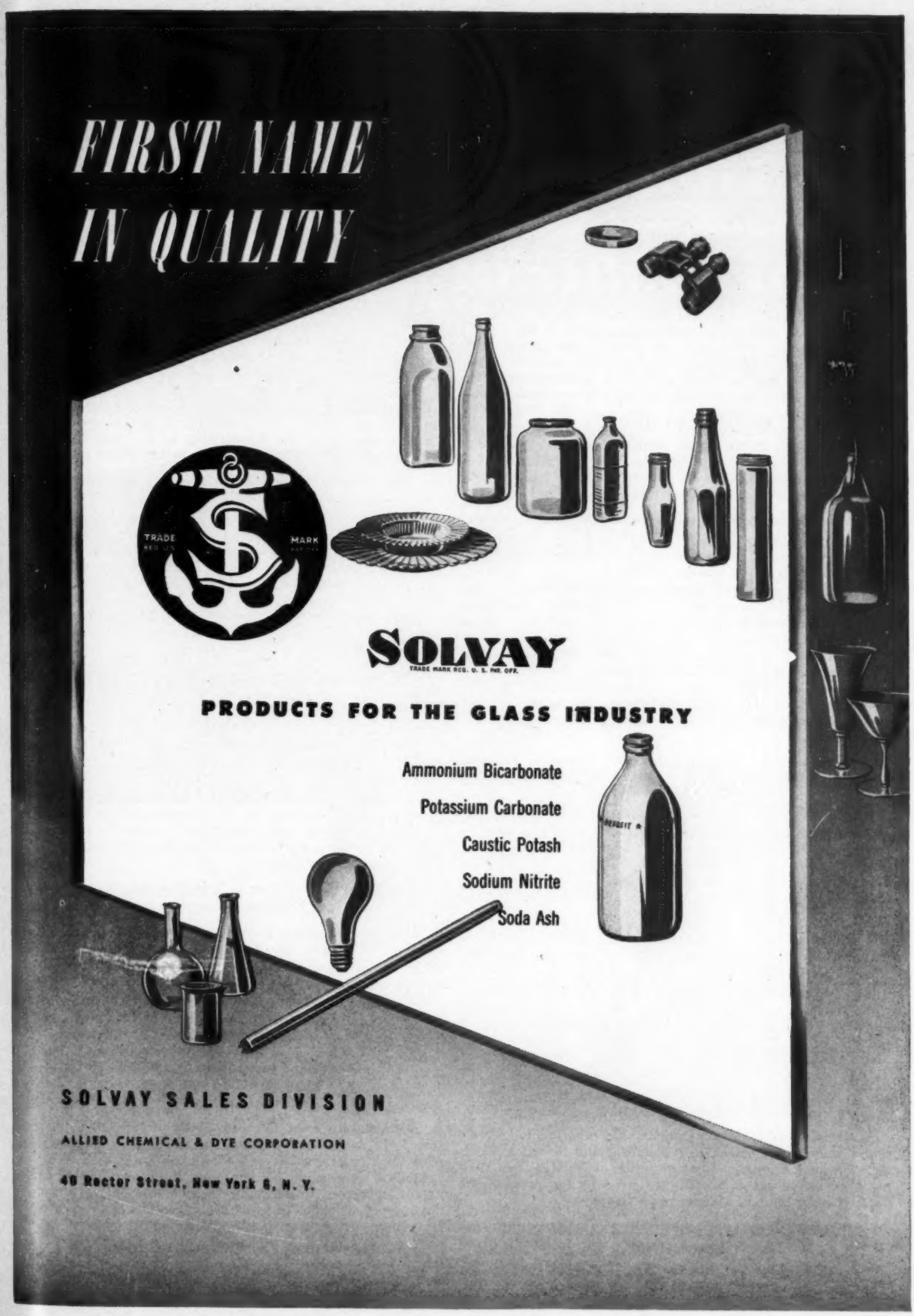
The Hays Corporation, Michigan City, Indiana, has issued its Bulletin 47-842 featuring Hays instruments and controllers for glass furnaces, ceramic kilns and enameling furnaces.

The booklet gives a brief resume of the company's background and then illustrates various instruments produced. Each instrument is accompanied by descriptive material concerning the function of each. Complete units are illustrated by line drawings with text, giving the relation of each individual instrument or controller to the entire operation. One line drawing is devoted to a complete gas fired glass tank furnace.

Minnesota Mining and Manufacturing Co., 901 Fauquier Avenue, St. Paul 6, Minn., is offering a new brochure entitled "3M Adhesives in Industry."

The 28-page brochure contains 40 pictures, cites 18 case histories and lists 26 of the more than 1,000 formulae offered by the company's adhesives and coatings division in Detroit.

Illustrated are bonding operations such as Plexiglas-to-Plexiglas, glass top to glass sides in display fixtures, plywood-to-metal, protective and anti-corrosion coatings for metal, etc. A table is shown giving the various adhesives, formula number, color, base, how applied and general properties and typical uses.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(Continued from page 193)

isolated grains of this compound; and (2) influence of minor constituents (0.5 and 3%) on the melting rate of the glass batch mentioned. The temperature of minimum emanation release, assumed to define the melting rate, is, for instance, decreased 100°C. by NaCl.

Wednesday Afternoon, April 28, 1948
2:00 P.M.-5:30 P.M.
Grand Ballroom

15. Surface Properties of Glass as Affected by Heavy-Metal Ions. *By W. A. Weyl: Glass Science Research Foundation, State College, Pa.*

The participation of certain heavy-metal ions in the structure of crystals and glasses differs from those of Mg^{++}, Ca^{++}, and other glass constituents which have the structure of noble-gas atoms (eight outer electrons). Not only Pb^{++}, Sn^{++}, but Cu^{++}, Co^{++}, and Ni^{++} have a tendency to form asymmetrical groups in which the metal ions are not surrounded symmetrically by the neighboring oxygen ion. The influence of these asymmetrical groups on some properties of glasses is discussed. Surface properties, such as surface tension, adhesion to metals, friction of the glass surface and its resistance to weathering, can be greatly changed by bringing heavy-metal ions into the surface layer.

16. Some Adhesion Phenomena Involving Glasses, Metals, and Fused Salts. *By Evelyn C. Marboe, W. D. Smiley and W. A. Weyl: Glass Science Research Foundation, State College, Pa.*

Many fused salts and glasses adhere tenaciously to the platinum crucible or glazed porcelain container in which they were melted; others fall out in one piece on tapping the crucible. The nature of the forces between ionic materials and metals is briefly discussed. The formation of capillary-active groups in glasses can prevent the melts from adhering to the wall of the crucible. Heavy-metal halides were found to be particularly effective in preventing adhesion at low temperature and, in some cases, even wetting at high temperature.

17. Hygroscopicity of Soda-Lime-Silica Container Glasses. *By F. R. Matson: Research Laboratories, Armstrong Cork Company, Lancaster, Pa.*

Powdered glass samples were exposed to an atmosphere of 98% relative humidity at 100°F. for 3 days. Commercial bottles and laboratory melts which systematically covered the field of container compositions were tested. The resulting gain in weight of the glasses, which is a function of their chemical compositions, can serve as an accelerated test of rate of weathering.

18. Effect of Rinsing on Chemical Durability of a Container Glass. *By K. C. Lyon: Research Laboratories, Armstrong Cork Company, Lancaster, Pa.*

New soda-dolomite lime-silica glass bottles were rinsed with 0.001 *N* solutions of several chlorides, sulfates, and nitrates. The bottles were then rinsed with doubly distilled water and subjected to an autoclave test for alkali extraction by water. Of the compounds tested, those of copper caused the greatest reduction in alkali extraction.

19. Outgassing of Vycor Brand Glasses and Silica Glass. *By B. J. Todd: Corning Glass Works, Corning, N. Y.*

A series of bake-out experiments are reported for Vycor brand glasses Nos. 7900, 7910, and 7911 and for silica glass. Relative total amounts of gas evolution at 700°C., after having been baked out at 800°C., are given by the proportions 36, 6, 1, 1, for the four glasses, respectively.

MATERIALS AND EQUIPMENT DIVISION PROGRAM

Tuesday Forenoon, April 27, 1948
9:00 A.M.-11:45 A.M.
Palmer House: Room 18

Session on Fuels and Materials Handling

1. Materials-Handling Problems in the Glass Industry. *By W. R. Lester: Maryland Glass Corporation, Baltimore 30, Md.*

As an introduction to the subject of materials handling in the glass industry, the flow of materials from the railroad car to the melting end of the glass furnace is discussed from the "quantity of material" and the "quality of finished product" viewpoints. In general, the following phases are covered: (1) material-handling factors in plant layout, (2) methods of unloading and transporting raw materials to "use" storage, (3) raw-material storage, (4) batch mixing, (5) mixed-batch transportation and storage, and (6) feeding of mixed batch into furnace.

2. Modern Raw-Materials Handling Systems. *By A. S. Milner: The Milner Company, Muncie, Ind.*

This paper deals with (1) raw-materials handling, practical storage facilities, and accurately controlled batch preparation and distribution as a vital requisite to uniform, low-cost glass production; (2) the unloading and positive location of individual batch ingredients into correct receptacles; (3) problems in the determination of practical storage capacities; (4) efficient feeding and accurate weighing to insure uniform batch; (5) collection of the weighed batch; (6) introduction of the decolorizing agent; and (7) mixing and transportation of mixed batch to the melting furnaces.

3. Air-Activated Conveying Systems. *By M. J. Bozich: The Convair Corporation, Pittsburgh 19, Pa.*

This paper describes a recently developed system of elevating and conveying raw materials and mixed batch in a closed system by air activation. A great variety of materials, including (1) foodstuffs, such as powdered shortening, (2) coal in dust or lump form, (3) glass cullet and mixed glass batches, (4) certain types of clays, and (5) wet filter cake, is conveyed for short or long distances and may be delivered without segregation of mixed materials at accurately predetermined rates.

Tuesday Afternoon, April 27, 1948
1:00 P.M.-3:45 P.M.
Room 18

4. Air-Activated Conveying Systems. *By E. S. McDowell: Robinson Air-Activated Conveyor Systems, Incorporated, New York, N. Y.*

A recently developed system for conveying raw materials through a closed system by air activation is described. Details of principle of operation, types of materials conveyed, and application of the system to specific conveying and elevating problems are given.

5. Lift Trucks and Pallets in Materials Handling. *By J. H. W. Conklin: Clark Equipment Company, Battle Creek, Mich.*

6. Overhead Conveying Systems in the Glass and Clay-working Industries. *By A. F. Anjesky: Cleveland Tramrail Division, Cleveland Crane and Engineering Company, Wickliffe, Ohio.*

The general subject of materials handling in industry, with special reference to the particular problems existing in various branches of the ceramic industry, is discussed.

Wednesday Forenoon, April 28, 1948
9:00 A.M.-11:45 A.M.
Room 18

7. Wollastonite as a Ceramic Material. *By A. J. Kirsch and J. F. McMahon: Department of Ceramic Engineering, New York State College of Ceramics, Alfred, N. Y.*

Studies were made to determine the feasibility of using natural-occurring wollastonite in glass and glaze compositions. Special bodies in which wollastonite was the principal ingredient were prepared, and their properties are presented.

8. Precision Method for Thermal Analysis. *By R. M. Gruver: Division of Ceramics, The Pennsylvania State College, State College, Pa.*

(Continued on page 220)

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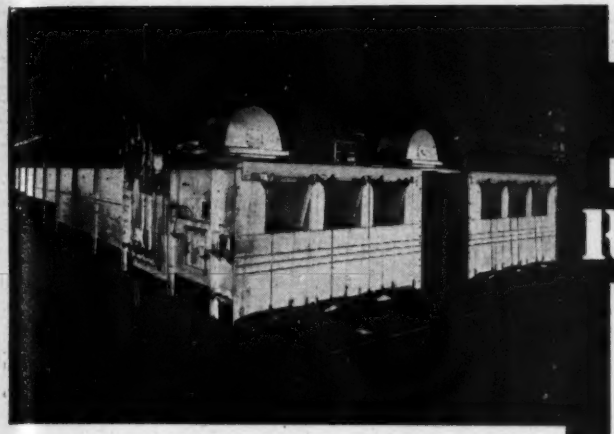

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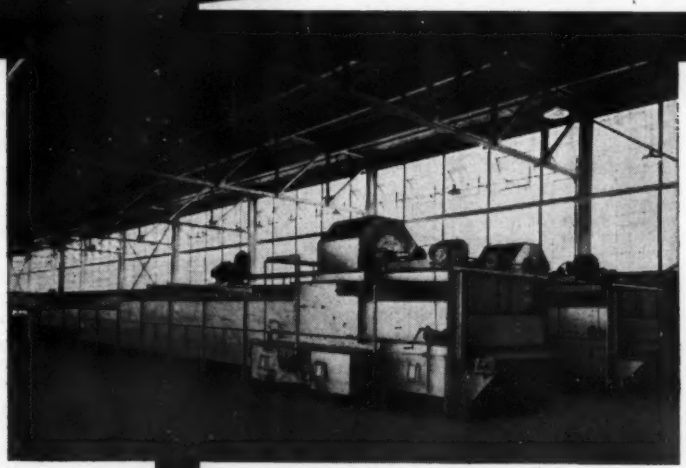

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(*Continued from page* 218)

A continuous recording potentiometer, measuring and reproducing accurately heat effects of 0.1° to 500°C., is used to measure the differential temperature between the sample and the material. The temperature rise of the sample and reference material is controlled to within 2°C. of a uniform rate (generally 400°C. per hour) by a continuous-voltage adjustment-type program controller. Properties of the sample holder differ from the usual holder described in the literature. The holder has low heat capacity, high conductivity, and small mass. These properties necessitate a uniform temperature area in the furnace.

REFRACTORIES DIVISION PROGRAM

Tuesday Forenoon, April 27, 1948
9:30 A.M.-12:30 P.M.
Palmer House: Room 14

2. Selection of Refractories for Electric Furnaces. *By L. L. Gill: Technical Department, Harbison-Walker Refractories Company, Pittsburgh, Pa.*

3. Effects of Operation on Refractories of Electric Furnaces. *By John Tjemmes: Electro-Alloys Division, American Brake Shoe Company, Mewah, N. J.*

Tuesday Afternoon, April 27, 1948
2:30 P.M.-5:30 P.M.
Room 14

7. Improvement of Analytical Control for Silica-Brick Refractory. *By J. T. Roza: National Spectrographic Laboratories, Incorporated, 6300 Euclid Avenue, Cleveland 3, Ohio.*

The prevalent use of silica brick has focused attention upon the need for control and improvement in quality. A review of the methods available reveals that many laboratory tests have been developed to avert expensive trial testing. It is significant, however, that the chemical knowledge of this product has lagged owing to several factors: (1) difficulty in sampling, (2) the tedious and time-consuming aspects of wet chemical methods, and (3) the consequent lack of knowledge of the deleterious effects of certain secondary constituents. One of the newer analytical tools has been the spectrograph. A total-energy method has been developed to permit analysis for $A_2l_2O_3$, MgO, Fe_2O_3, CaO, Na_2O, TiO_2, K_2O, ZrO_2, MnO_2, and Li_2O. The total time required is about 30 minutes for sample preparation and 25 minutes for the spectrographic process. Present accuracy is well within production limits.

This method is also suitable in the general ceramic field for the analysis of glass sand.

8. Critical Survey of Refractory Pebbles. *By Louis C. Bearer: Chemical Engineering Department, Phillips Petroleum Company, Bartlesville, Okla.*

9. Use of Alkali-Metal Silicates in Refractories. *By J. I. Mueller: Missouri School of Mines, Rolla, Mo.*

The present state of knowledge on the action of sodium potassium and lithium silicates in fire-clay mixtures is reviewed. Fundamental laws of colloidal chemistry are applied to explain peculiar actions observed in such mixtures.

Wednesday Forenoon, April 28, 1948
9:30 A.M.-12:30 P.M.
Room 14

12. High-Temperature Laboratory Kiln. *By W. P. Keith: Norton Company, Worcester 6, Mass.*

13. Improved Roberts Control for Laboratory Furnaces. *By W. B. Crandall, M. Burzycki and V. D. Fréchette: Department of Ceramic Engineering, New York State College of Ceramics, Alfred, N. Y.*

Automatic precision control of a platinum-wound furnace for use in the study of high-temperature reactions was secured by the construction of an improved controller of the Wheatstone-bridge type, described by Roberts, in which the wire heater of the furnace acted as the thermosensitive element for control. Improvements included (1) a filter circuit for elimination of a.-c. harmonics, (2) a thyratron bias to broaden the "control angle," (3) voltage stabilization for the thyratron filament, and (4) design as a compact and portable assembly. Operating from a nominal 110-volt a.-c. supply, which was subject to variation between 95 and 130 volts and included a prominent fifth harmonic, the controller proved to be capable of maintaining temperatures up to the limit of the winding with fluctuations of less than 1°C. over long periods. Aging of the winding resulted in a slow systematic drift to lower temperatures. Response to compensate for departures from the setting temperature, caused by the introduction of specimens, was extremely rapid and overrunning was absent.

14. Microscopy of High-Temperature Phenomena. *By Henry N. Baumann, Jr.: Carborundum Company, Niagara Falls, N. Y.*

The high-temperature microscope of the Research Laboratory of the Carborundum Company is described. The optical design, new in principle, is shown, and its incorporation into a practical thermal microscope is detailed. The principles and practices of thermal microscopy, including cinemicrophotography, are discussed and their applications in ceramic and refractory experimental work are indicated.

Wednesday Afternoon, April 28, 1948
2:30 P.M.-5:30 P.M.
Room 14

16. Method of Particle-Size Determination by Means of the Microscope. *By V. D. Fréchette and H. I. Sephton: New York State College of Ceramics, Alfred, N. Y.*

A method of particle-size determination in the subsieve range was developed to facilitate measurement with no loss in the precision inherent in the microscopic technique. Features of the method include (1) dispersion of the sample in warm, raw Canada balsam, (2) classification of the individual particles with respect to Martin's diameter by means of an external gauge which is visible through the Abbe drawing camera (camera lucida), and (3) examination of the mount at three successive magnifications. Either a micrometer-driven stage or an internal standard is used to reduce the respective particle counts to the same basis as percentage of the total sample. The data, for example, may be represented in the form of a frequency-distribution curve and calculated to yield specific surface (average diameter with respect to surface).

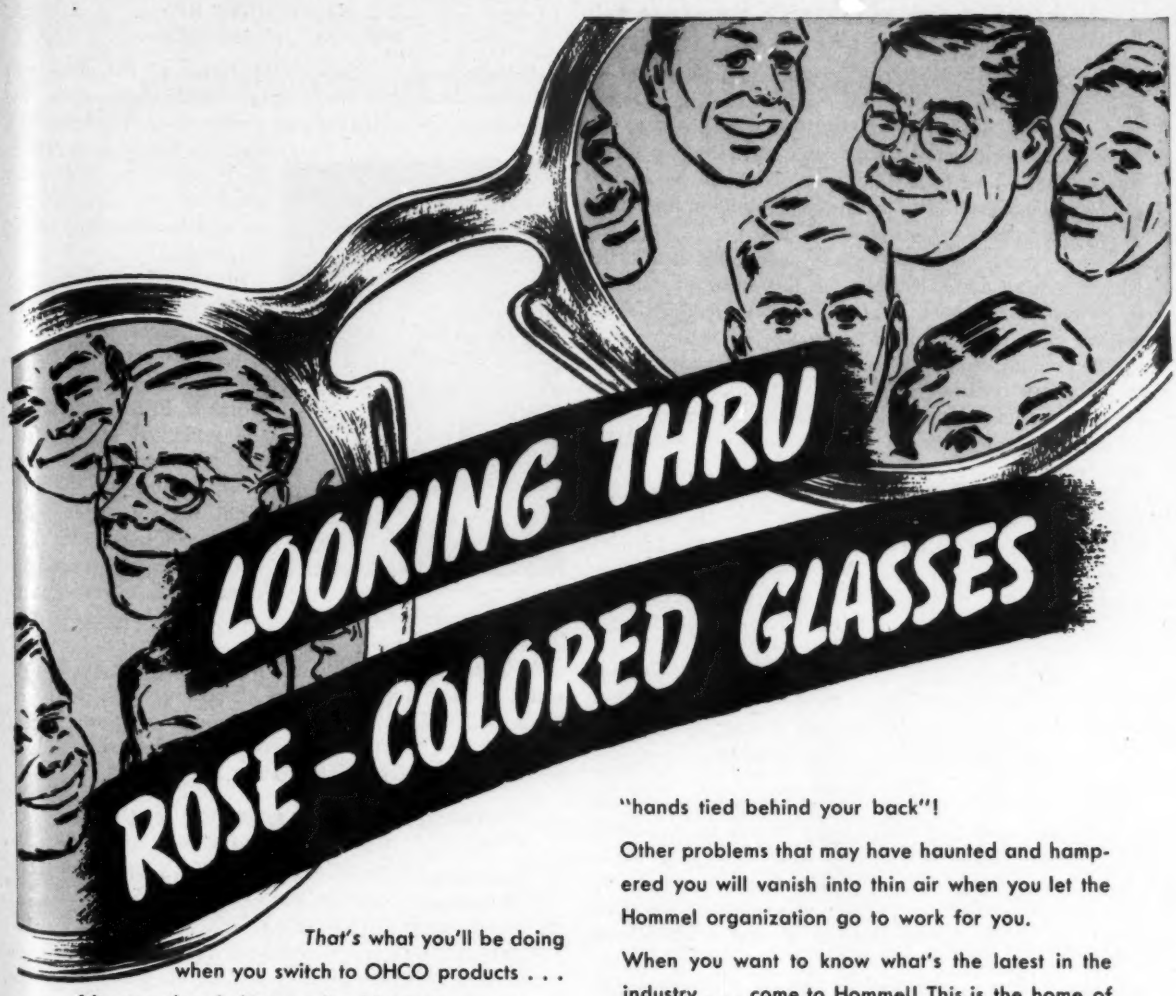
17. Use of High-Temperature X-Ray Diffraction Methods in Refractory Research. *By F. A. Hummel: Division of Ceramics, The Pennsylvania State College, State College, Pa.*

High-temperature X-ray diffraction patterns are useful in the investigation of fundamental properties of refractories and purified ceramic compounds. Phase changes can be detected by obtaining complete patterns above and below the expected inversion temperature or by observing the behavior of one intense diffraction peak as the temperature of the specimen is increased through the inversion temperature. The latter method is fast and capable of great accuracy in the determination of temperatures at which inversions occur. Examples of data on the low-high quartz inversion are given as well as data for a group of alkaline-earth phosphates.

18. Note on Microsampling of Ceramic Materials for Analysis. *By L. B. Bassett and V. D. Fréchette: New York State College of Ceramics, Alfred, N. Y.*

The diamond microsampler consists of a high-speed diamond drill and rotating specimen mount capable of removing successive layers as thin as 0.01 in. from fired ceramic specimens. Provision is made for accurately adjusting the depth of cut and the area sampled. Contamination and loss of sample are small. The technique has been found valuable in procuring samples for petrographic, spectrographic, and X-ray studies.

(*Continued on page* 226)



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SWEDISH GLASS INSTITUTE BROADENS SCOPE OF PUBLICATION

In the August 1947 issue of *Glasteknisk Tidskrift*, official publication of Sweden's glass research institute, Mr. B. Simmingskold, who heads the institute, published the following foreword outlining the expanded interest of its publication. THE GLASS INDUSTRY hopes to be able to publish from time to time translations of important papers which may appear in *Glasteknisk Tidskrift*.

At the beginning of 1946, the Governing Board of the Glass Institute decided to attempt to issue a publication in which glass technological problems would be considered in the form of elementary articles about the properties and manufacture of glass, the results of the researches of the Glass Institute, translations and abstracts of foreign researches and technical advances as well as questions in general which might be of interest to the glass industry.

The publication was given the name "Stiftelsen Glas-Institutet i Vaxjo, Medlemskrift" (Bulletin for Members of the Glass Institute at Vaxjo). The first, the January 1946 number, comprised an issue of 300 copies and contained an article relating to the properties of glass making raw materials. The responsible publisher is Director Y. W. Anderberg of Gothenberg.

The publication has aimed to provide articles suitable even for those who lack more thoroughgoing theoretical knowledge of glass technology, but it has, nevertheless, been necessary to include various formulas, theoretical arguments, etc.

It is planned, if possible, to issue six numbers per year. The present number is accordingly No. 10 in the series.

It became apparent very soon that there was a pronounced interest in our publication among management men as well as among foremen and workers in the glass factories and that the publication is being studied by a great many individuals interested in glass technological problems. Numerous copies are being sent to our neighboring countries. Proof of this interest is the constantly increasing edition which has now attained 700 copies.

Inasmuch as the publication is now read by a great many who are not directly connected with the Glass Institute, the Board has found it advisable to change the name to "Glasteknisk Tidskrift, Utgiven av Glasinstitutet i Vaxjo" (Journal of Glass Technology, published by the Glass Institute at Vaxjo). At the same time, as may be seen by the present number, an attempt has been made to give the publication a more attractive appearance. The art layout is the work of Miss I. Lundeen, Orrefors. The plan of contents, numbering of issues and pages, etc., will not be effected by this change.

A.S.T.M. ANNOUNCES ANNUAL MEETING

The 1948 Annual Meeting of the American Society for Testing Materials, the 51st such session of this national technical organization, is to be held in Detroit the week beginning June 21.

During this week there will be some 20 technical sessions, with a large number of technical papers and reports in the field of materials. There will be more than 300 meetings of the Society's technical committees, concentrating their work on standards and research in materials.

J. RALPH BOYD OF IMPERIAL GLASS DIES

J. Ralph Boyd, member of the Board of Directors and Secretary-Treasurer of Imperial Glass Corporation for over thirty-five years and an employee of that company since its inception in 1904, died from a sudden heart attack at the residence of his son in Wheeling, West Virginia.

Mr. Boyd was engaged in the hand glass industry his full lifetime. As a young man, he was first employed by the old Crystal Glass Works in Bridgeport, Ohio, and remained at that factory for a short time after it was a unit of the National Glass Combine. He became affiliated with Imperial with the original founders of the company who were composed mostly of the former owners of the old Crystal.

Mr. Boyd is survived by his wife, Annie McLain Boyd; sons, Donald and George of Wheeling, Dr. John of Moundsville, West Virginia, and Thomas of Puerto Rico; a brother, G. Roy Boyd, Treasurer of Cambridge Glass Company, and 5 grandchildren.

COMMERCE DEPARTMENT REPORT ON GLASS YARNS

A comprehensive list of 375 German, American, French, British and other foreign patents pertaining to the production of glass threads, glass fabrics and glass insulation for electro-technical and heat insulating purposes is contained in a report now on sale by the Office of Technical Services, Department of Commerce.

The report is a translation of a German technical paper obtained from the Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, by OTS investigator, Glenn H. Treat, following his investigation of the German electrical equipment manufacturing industry. The report also contains a general discussion of the use of glass yarns as insulating materials in the German electrical industry.

The list of patents is divided into three groups: Group A (162 patents) covers processes and devices for the production of glass fibers, glass yarn and glass foil; Group B (112 patents) covers the use of glass insulation for electrical cables and conducting wires and coils; and Group C (101 patents) covers the production of other insulating materials, such as paper, insulating press devices and the like from glass threads and glass fabrics, and the use of glass insulation for condensers, current-reverser-lamellas, and other purposes.

Mimeographed copies of the report, PB-78681-T, "Glass yarns as an insulating material for the electrical industry" (translated from the German, 84 pages), are available for $2.50. Orders should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order payable to the Treasurer of the United States.

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(*Continued from page* 207)

d. *Role of the permeability of glass to radiation.* Until now, we have introduced into the thermal changes between the different parts of the tank only the direct transference of heat by material (convection) displacement. When we spoke of glass cooling upon contact with the wall, we did not suppose that this wall, or this glass, could be re-heated by radiation through the glass. What do we know about this question? An extremely long article would not be sufficient to exhaust its possibilities. There are defenders of athermaneity: the molten glass would be practically opaque to all radiation under a small thickness (Buckingham, F. W. Preston); and those of diathermaneity (transparency) which are found especially among practical glass makers who have observed that in molten glass the bottom of the tank is hard and cold.

Let us consider in an ordinary tank of one meter of depth a vertical prism of glass of one square meter section. In the hottest zone of a tank, the bottom of silica-alumina blocks of 30 cm. thickness, loses about 5 kw-hr. [per hr.?]. Where does this energy come from? *Conduction* seems outside the question. Gelhoff and Thomas have measured by thermocouple the vertical variation of temperature in a throat furnace in flint glass. The surface temperature of the bath being about 1450°C., that of the bottom glass was about 1280°. The pure conductivity of the molten glass could only be extrapolated, however with enough accuracy, from the measurements of Seemann which are carried to 600°, the temperature at which convection and re-radiation are nil. Conductivity of 0,01 C.G.S. is found. This is the order of magnitude of the values admitted by C. Cone and by W. Schneekloth. The intensity of the conduction flow would thus be 170 x 10^{-4} Cal/cm²/sec. or 0,04 kw.-hr./m²/hr., a figure out of proportion to the energy which must be effectively transported to the bottom in order to account for the losses.

Concerning the *transmission by radiation*, all scientific hypothesis is lacking at the highest temperatures because of experimental difficulties. The measures of emission of molten droplets[26] can be considered only as indications.

Recently, Turner, Halle and Eric Preston[27] have published the results of long observations on a miniature tank containing molten glass at small depth for practically eliminating convection. The penetration of heat is deduced from a rigorous accounting of the losses from the tank in each of its portions and from the control of quantity of heat used in the melter. From the ensemble of these results, we deduce that for transmitting 1 kw.-hr./hr. through a section of 1 cm², a temperature gradient of 0.67°/cm. is necessary. Reconsidering the preceding concrete case and placing it in the more favorable case of a constant gradient, the difference of temperature between the surface and the bottom must be double that which was experimentally proven for transmitting the required energy.

The radiation is therefore absolutely insufficient. This supports the opinion of those who think that convection plays a preponderant role.

However, the physicist is acquainted with general laws relating to the transmission (of radiant energy) as the

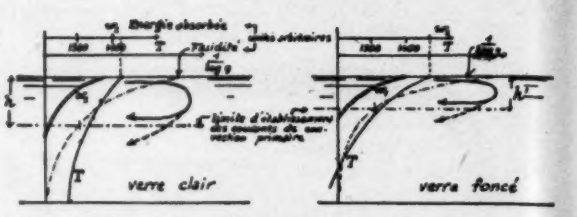

Fig. 31. verre clair = clear glass. verre fonce = dark glass.

temperature is raised: there is a general slackening of the bonds between molecular aggregates, and a displacement of the absorption-bands towards longer wave-lengths. Glass, which up to about 600°C. is virtually a black-body, inasmuch as its infra-red absorption band covers completely the emission-curve of a black-body for the same temperature, begins, above that temperature, to fall below the front part of that curve, over the range in which glass is transparent, which range is displaced towards the infra-red. At about 1000°C., molten glass may be substantially different from a black-body. At still higher temperatures, the ultra-violet absorption-band, displaced well into the visible part of the spectrum, begins to overlap the black-body emissivity-curve, whose crest is moving to meet it. It is entirely likely therefore that at high temperatures the diathermancy of molten glass may be very slight.

C. Cone has calculated, from a hazardous extrapolation, it is true, some coefficients for solid glass; that for an "ordinary" glass (flint) only 1.8% of radiant energy falling on the surface penetrates beneath 30 cms. of thickness of the bath.

What is needed, therefore, is the reconciliation of this expectation of the physicists with the observations of the glassmakers on clear and deep-colored glass (these qualifications being relative to visible light, which, as remarked by Preston, does not play a very large role in heat radiation).

We admit at the outset a *small difference* of permeability between the "clear" glass and "dark-colored" glass. A *small difference* of temperature in depth is a result and therefore a *small difference* of viscosity (Figure 31). To simplify matters, let us admit that convection involves only a corresponding layer at a lower viscosity at a given limit. This convection will be established for example at a height h in the case of clear glass, and at an inferior height h' in the case of dark glass. The preponderant influence of the *height* on the establishment of convection currents has been seen. *Important variations* in the speed of currents which can excavate and reheat the deep layers are results of these *small initial differences*. This interpretation would be in agreement with the observations summarized in the table represented by Figure 24.

In order to explain the phenomena proven in the tanks of clear glass and dark glass, we recognize finally that diathermaneity has a role of priming, of releasing, but we think that the phenomenon is considerably amplified by associated convection currents.

● A record in production and sales of its glass and plastics products was made by Libbey-Owens-Ford Glass Company in 1947, the annual report to shareholders reveals.

[26] Eitel, W., and Lang, *Glastechn. Ber.*, 1932, p. 78.
[27] *Journ. Soc. Glass Tech.*, 23, 1939, p. 171.

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FLAT GLASS MONOPOLY TRIAL OPENS IN TOLEDO . . .

(*Continued from page* 199)

Ross W. Schumaker, also speaking for Pittsburgh Plate Glass Company, declared the true story is one "of economics and technology and not one of conspiracy or monopoly."

Joseph A. Yager, speaking for the National Glass Distributors Association, maintained that the association was not controlled by large companies and asked dismissal of the action against it.

The current trial, which began March 1, this year, before Judge Frank L. Kloeb in the U. S. District Court at Toledo, Ohio, is the outcome of a civil suit filed by the government on May 23, 1945 against Libbey-Owens-Ford Glass Co., the Pittsburgh Plate Glass Company, American Window Glass Company, Fourco Glass Company, Franklin Glass Corporation, Rolland Glass Company, American Security Company, Blue Ridge Glass Company, Corning Glass Works, sixteen individual officers of corporate defendants, and the National Glass Distributors Association. On September 5, 1946 Corning Glass Works signed a consent action removing it entirely from the suit. The number of individual defendants is now eleven.

The government's complaint charged monopolistic activities in violation of the Sherman Anti-Trust Act, the Wilson Act and the Clayton Act in respect to foreign and domestic licenses and transactions and in regard to marketing and distribution practices.

It charged specifically that in 1928 Libbey-Owens-Ford and Pittsburgh Plate embarked upon a program to secure a monopoly of the flat glass business in the United States: that the program was effected by a series of mergers and consolidations; by the purchase and subsequent dismantling of competing plants; by adoption of joint trade practices, including division of fields, territories and customers, limitation of production, and price fixing at all levels of distribution. In addition, the complaint alleged that competition with foreign manufacturers was eliminated through agreements by which the latter agreed not to export flat glass to the United States in return for increased financial support and exclusive rights abroad to the defendants' patents.

The complaint asked: divestiture of all flat glass plants, except one each, owned by Pittsburgh Plate Glass Co., Libbey-Owens-Ford Glass Company and American Window Glass Company; dissolution of Fourco Company and the National Glass Distributors Association; cancellation of all restrictive agreements between American and foreign companies; royalty-free licensing on all existing patents and compulsory licensing on a reasonable royalty basis of all patents acquired in the future, including improvements on existing patents; divestiture by Pittsburgh Plate Glass Company of its 106 warehouses and retail stores.

Among the government witnesses who have testified during the trial are Nestor R. Scohy, former secretary of the Scohy Flat Glass Company, Sisterville, W. Va., and Burnham W. Diggle, acting deputy housing expeditor for rent control in Washington and formerly engaged in sales activities for several small manufacturers of window glass.

Mr. Scohy described conditions in the industry as affected by the introduction of machine production, explained how competition operated, and testified with respect to sales quotas that "Nobody set any definite figures, for Fourco or anybody else."

Mr. Diggle referred to informal, off-the-record discussions as to the desirability of price- and quota-stabilization but failed to cite any instances of positive action.

By the third week of the trial the plaintiff had offered nearly 400 exhibits of documentary evidence, such as letters, minutes of meetings, sales circulars, etc. More than 1500 pages of records had been made. Documents related to such matters as transfers of ownership of glass companies and plants, the formation of Fourco, items about prices, tariffs and wage increases tied to glass prices, sales contracts, etc.

It has been indicated that the plaintiff's side would not be finished before May 1, and that the defense will start in autumn.

A.C.S. TO CELEBRATE GOLDEN JUBILEE AT CHICAGO . . .

(*Continued from page* 220)

19. Investigation of Abrasion Resistance of Various Refractories. *By Kenneth A. Baab and Hobart M. Kraner: Bethlehem Steel Company, Bethlehem, Pa.*

This paper discusses a new abrasion test for refractories consisting of a controlled sandblasting operation wherein various brands of brick were tested. Graphs are included which show correlations for abrasion loss per hour against other properties for the brands tested. Data and charts which compare this abrasion test with the A.S.T.M. rattler test for paving brick are also included.

Thursday Forenoon, April 29, 1948
9:30 A.M.-12:30 P.M.
Room 14

21. Some Thermochemical Properties of Important Ceramic Oxides. *By R. A. Schoenlaub: Sylvester and Company, 552 Terminal Tower, Cleveland 13, Ohio.*

A scale of fourteen minerals, varying from acidic to basic in approximately equal increments, was devised. The compatibility relationship of SiO_2, TiO_2, Al_2O_3, Cr_2O_3, CeO_2, ThO_2, ZrO_2, BeO, MgO, and CaO and of five refractory compounds to the scale minerals was experimentally or otherwise determined. Using the proportion of scale minerals with which an oxide is compatible, a measure of the relative thermochemical stability is obtained, The position of the pattern of compatibility also disclosed the relative acidity or basicity.

25. Properties and Uses of Pure-Oxide Heavy Refractories. *By O. J. Whittemore, Jr.: Norton Company, Worcester 6, Mass.*

Thermal conductivity, high-temperature load-bearing resistance, reheat shrinkage, and porosity were determined on new "pure-oxide heavy" refractories of alumina, magnesia, and stabilized zirconia refractories to at least 2300°C. The thermal conductivity of alumina refractories was found to vary directly with density, and four mixtures are described with conductivities ranging from 6 to 18 B.t.u. per hour per sq. ft., in. per °F. at 1800°F. Stabilized zirconia refractories, although twice the bulk density of fire-clay brick, have lower thermal conductivity.

• The Pyrometer Instrument Company has announced the completion of its new plant to which all facilities, both laboratory and office, will move. The new plant is located at Bergenfield, New Jersey.

WINTER MEETING OF OPTICAL SOCIETY . . .

(Continued from page 205)

ards are used in the colorimetry of transparent materials such as rosin, honey, etc., and are usually expressed in single numbers referring to a particular standard solution or a glass specified by preparation or brand only.

In the session receiving the reports of the member societies, Dr. Hunter referred to the Color Program of the Atlantic City meeting of the American Ceramic Society as a major contribution. The papers constituting this special program have just appeared in the *Bulletin of the American Ceramic Society*. The program had been arranged by Dr. I. Balinkin, professor of physics, Cincinnati, together with Miss Dorothy Nickerson, color expert of the Department of Agriculture, and the secretary as well as a "spiritus rector" of the Council, and Mr. Pearce, American Ceramic Society secretary. Papers were by Dr. Balinkin, Dr. Weyl, F. Birren, C. Foss, D. Nickerson, R. Hunter and H. Remington.

Most of the individual talks presented before the Council referred to topics as far away from glass as fashion, architecture and painting. Mr. Doner, chief designer of Libbey-Owens-Ford, had an interesting story which he derived from glass house practice. When the company started the production of optical glass during the war, eye strain was found extreme under standard inspection conditions. A color engineering project was inaugurated to combat these difficulties and resulted in the development of a new, so-called "Daylight" maintenance painting now generally used in and beyond that organization. Standard machine and safety paints were harmonized with this "new look." Who can say what wall colors will do to us after hearing Mr. Doner describe the effect of the paint on manhood under the impact of femininity in the wartime shop.

COMMERCE DEPARTMENT ISSUES REPORT CONCERNING OPTICAL GLASS

A technical description of the processing of high purity neodymium and praseodymium compounds of particular interest to manufacturers of special optical glasses is contained in a report now available through the Office of Technical Services, Department of Commerce. The report was prepared for OTS by Joseph S. Smatko, Columbia University, following an investigation of the Auergesellschaft plant in Berlin, Germany.

In his investigation, Mr. Smatko hoped to find a process for the production of high purity neodymium and proseodymium compounds on a commercial scale, but only laboratory processes were found for producing 98 per cent purity salts.

Since the various rare earths differ from each other only in small degree insofar as properties of the compounds are concerned, lengthy and laborious procedures are necessary to affect a separation. Fractional crystallization is used to accomplish the purpose.

Techniques for processing neodymium, praseodymium and lanthanum compounds are discussed separately in the report. The report contains a diagram of a fractional crystallization scheme used by Auergesellschaft. Mimeographed copies of the report (PB-48428, Lanthanum, neodymium, praseodymium, 9 pages) are 25 cents.

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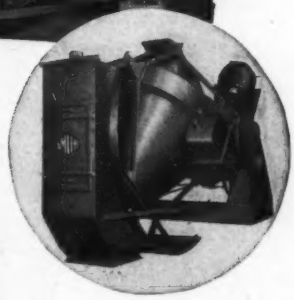

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Glass Batch MIXERS

BORIC OXIDE—ITS CHEMISTRY AND ROLE IN GLASS TECHNOLOGY . . .

(Continued from page 204)

low temperature region. The structure of a B_2O_3, SiO_2 glass is an intermediate between those of the two components. BO_3 triangles and SiO_4 tetrahedra are interlinked and this structure remains on cooling. No borosilicate formation will take place.

The second restriction refers to the B_2O_3 concentration in the glass. Our statement does not refer to glasses with 20% or more B_2O_3 because we learned previously that the change of BO_3 to BO_4 units is a characteristic feature of the first additions of B_2O_3 to a glass and ceases to take place if a value between 12% and 20% is exceeded.

The third restriction deals with the time factor. A molecular rearrangement of this type requires time. The bonds involved, B-O and Si-O bonds are both relatively strong. The temperature where the rearrangement from BO_3 to BO_4 units takes place is relatively low and as a result this change is sluggish. Danburite $CaO \cdot B_2O_3 \cdot 2SiO_2$ can be easily overheated and its structure does not break down as soon as its decomposition temperature is exceeded. As a result of this sluggish change, all properties of the borosilicate glasses are subject to a more pronounced change with annealing or compacting than those of pure silicate. Summarizing the characteristic features of boric oxide as a constituent of glasses we can say:

a) Boric oxide can form two different units which both can participate in the three dimensional network of a glass. The one unit is planar consisting of a triangle of oxygen ions with a boron ion in its center. The other unit is comparable with that of silicate glasses. Four oxygen ions form the corners of a tetrahedron, the center of which is occupied by the boron.

b) Boric oxide alone or in mixtures with SiO_2 forms BO_3 triangles which cause low melting temperature but due to their asymmetrical shape produce relatively high viscosity, low diffusion rate and sluggish molecular rearrangements.

c) Addition of basic oxides such as alkalies causes some of the BO_3 triangles to change into BO_4 tetrahedra. As the fourfold coordinate is not the natural one of boron, this change is restricted to certain concentration and temperature regions. BO_4 groups are favored if the B_2O_3 concentration does not exceed 15% and the temperature is low.

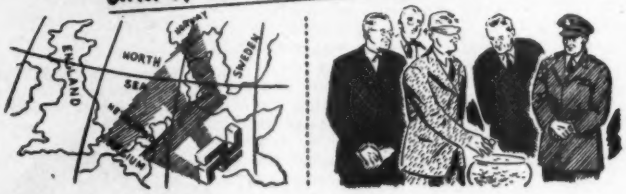
VINYL BASE CEMENT AVAILABLE

The Schwartz Chemical Company, Inc., 326 West 70th Street, New York 23, New York, has announced the manufacture of a versatile vinyl base cement for the adhering to themselves or to each other on an efficient production line basis of glass, crockery, mirrors, plastics, wood, metal rubber, leather and labels.

The company reports that two years of continuous research has resulted in the development of this all-purpose transparent water-white cement that is easy to apply and does not affect the material it is applied to, mirrors and thin plastics included. It requires only a one-surface application, has good wet "grab," remains permanently flexible and will not become brittle. It can easily be applied by brush, roller or spray and is resistant to water, oil, gasoline, vermin and mold. The manufacturer states it is completely non-staining and has excellent tensile strength.

*1907 was a great year . . .

and 1940 was one of world turmoil!



In 1940, Norway, Denmark, Belgium and the Netherlands were invaded by the Germans . . . Paris fell . . . Italy entered World War II on the side of Germany. The first United States peacetime compulsory military service was inaugurated when Secretary Stimson, blindfolded, drew Draft Card #158 from a glass bowl in Washington.

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GRANT BUILDING, PITTSBURGH, PA. ESTABLISHED 1907*

INVENTIONS AND INVENTORS...

(Continued from page 209)

to Purcell. This conveyor passes around a pair of sprockets 18 mounted on a shaft 17 by which the direction of travel of the conveyor is changed. Sprockets such as 25 are provided around which the conveyor passes at the end of its run. Suitable means are provided so that the height of the conveyor may be adjusted at the ware receiving end.

The wiper 15 is driven by a motor shown at the left of the figure, through a change-speed device which in turn drives a screw extending across the front of the lehr. A clutch is provided by which the direction of rotation of the screw is reversed when the wiper hits adjustable stops at either end of its travel. The clutch is arranged so that the wiper 15 moves at the same speed as the conveyor 10 on its idle stroke but at a slower speed on its working stroke, that is, to the right in the figure. The vibrating plate 13 is electrically actuated and is preferably made from a series of lips 14 to take care of any unevenness in the lehr belt.

By a proper adjustment of the speeds of the lehr belt, the ware may be spaced as desired but it is preferred to position the ware close together so as to prevent danger of falling over.

The following references are of record in the file of this patent: United States Patents: 1,148,005, Bogdanffy, July 27, 1915; 1,424,850, Purcell, Aug. 8, 1922; 1,501,602, Holmes, July 15, 1924; 1,509,063, Johnson, Sept. 16, 1924; 1,538,248, La France, May 19, 1925; 1,624,250, Johnson et al., Apr. 12, 1927; 1,637,714, Slick, Aug. 2, 1927; 1,817,373, Hopkins, Aug. 4, 1931; 1,833,951, Morton et al., Dec. 1, 1931; 1,883,362, Freese, Oct. 18, 1932; 2,008,572, White, July 16, 1935; and 2,094,787, Flint, Oct. 5, 1937.

REPORT ON BRITISH GLASS EXPORT

The British glassware industry is making good progress towards achievement of its export target set by the Government in the White Paper on exports.

The target fixed for mid-1948 for plate and sheet glass was given as £300,000 and this target has been achieved, while the target set for other glassware was £370,000, and at present £270,000 has been achieved. This shows that the industry is making a very substantial contribution to export figures and is well on the way towards achieving the desired target.

The situation depends very considerably, of course, upon the trend of world usage and the readiness of importing countries to accept imports. Failure to reach the target set had been due, in many instances, rather to bans imposed by importing countries than to any real lack of desire for the goods. Complaint of manufacturers has been that too often the Government target failed to take such contingencies into consideration. The following table gives the position of exports to date:

£ MILLIONS

	4th qtr. 1946	3rd qtr. 1947	4th qtr. 1947	Target mid-1948
Plate and sheet glass.....	0.25	0.25	0.30	0.30
Other glassware	0.28	0.26	0.27	0.37

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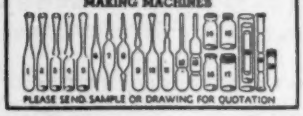

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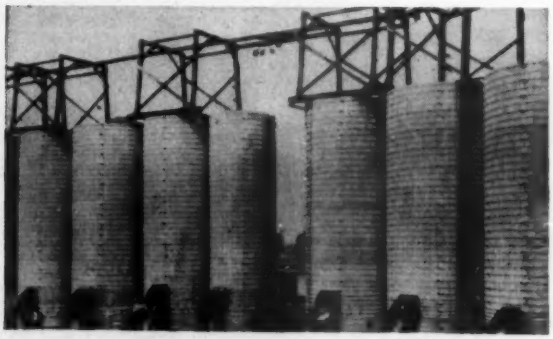

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Massey, Wood & West of Richmond, Va., store coal in ten Neff & Fry bins. Coal is hoisted into the bins with conveyors from dump pits, then loaded into delivery trucks by gravity.

Says the foreman, comparing this operation with one not so equipped, "We deliver more coal with half as many trucks."

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NEFF & FRY STORAGE BINS

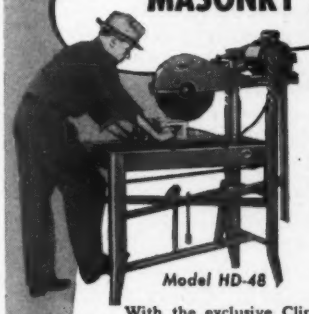
RAW MATERIALS PROCUREMENT PROBLEMS IN THE GLASS INDUSTRY...

(Continued from page 196)

price for several years. While it is my feeling that the buyer of corrugated cartons will be able to get the quantities needed, provided he is willing to pay the price, I do not see that there will be any over-supply of corrugated for some years to come.

Regarding prices of materials generally used in our industry, it is my prediction that they will hold about at the present levels unless we encounter a new round of wage increases, then it is anybody's guess. To the suppliers who look to the glass business for your volume, I leave this thought: Today the glass business needs all of the materials which are being produced and we simply cannot afford to have any of you quit producing. This condition might lead some of you to the conclusion that now is the time to get all the traffic will bear. However, there is a limit to the prices which glass can demand in a competitive market. I do not mean a competitive market among glass producers, but the competition which comes from other materials such as steel, paper, and plastics. Any cost which places glass at a disadvantage with these materials limits the markets which glass can reach. In the end glass salesmen are selling sand, soda ash, lime and lime products, and other materials which are purchased by the purchasing agent for the glass plants, and unless prices for these materials permit competitive costs and a competitive selling price, it will result in diminishing volume in glass sales and a corresponding diminishing volume in material purchases.

CUTS WET-CUTS DRY
The NEW 1948
CLIPPER
MASONRY SAW



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GLASS FIBERS, INC. NAMES W. M. FRASER VICE PRESIDENT AND EASTERN REPRESENTATIVE

William M. Fraser has been appointed Vice President of Glass Fibers, Inc. in charge of Eastern Textile Sales and Engineering, according to an announcement made by service headquarters for textile customers in the north and southeast sections.

Mr. Fraser graduated from Brown University in 1919 and immediately began his textile career in R. H. Barnard, President and General Manager.

In conjunction with Mr. Fraser's appointment, Glass Fibers, Inc. will establish Eastern offices in the Hospital Trust Building, Providence, Rhode Island, as the engineering department of Fales and Jenks Machine Company and the Woonsocket Machine and Press Company, advancing to the position of Asistant General Manager. For the next ten years, he was identified with both The Pantex Pressing Machine Company and as General Manager of the H & B American Machine Company of Pawtucket. From 1938 until he recently resigned, Mr. Fraser was Vice President and General Manager of The Atwood Machine Company, Stonington, Connecticut.

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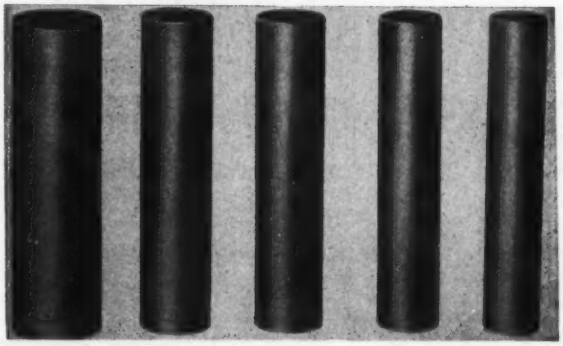
North Portland, Oregon — Houston 1, Texas

GUNITE



ROUND BAR STOCK

Gunite can be machined with relative ease, yet has a high density that will take a brilliant polish. Round Bar Stock is available in 18 sizes from ¾" to 5" diameter, all bars 14" long. There is a suitable Gunite alloy for many types of glass-making castings such as Plungers, Ring Sticks, Neck Rings, Guide Rings, Moulds, Blanks, Bottom Plates, etc.

MADE BY GUNITE FOUNDRIES ROCKFORD, ILLINOIS

GLASS COMPANY FILES APPLICATION FOR REORGANIZATION

It has been announced that the Neville Island Glass Company, Inc., has filed a petition under the Chandler Act with the District Court of the United States for the Western District of Pennsylvania for the purpose of formulating a Plan of Reorganization for the benefit of its creditors. At the same time, a petition was presented requesting authority to continue operations of the plant.

Temporary trustees were appointed by the District Court to take charge of the affairs of the company consisting of Joseph H. Bialas, Attorney-at-Law, as Independent Trustee, and R. M. Marshall, a director of the company and President of Pittsburgh Coke and Chemical Company.

WESTINGHOUSE DEVELOPS NEW STERILAMP

Westinghouse Lamp Division, Bloomfield, New Jersey, has announced the development of a new bactericidal lamp that emits more than twice as much ultraviolet radiation as any lamp heretofore available. It is a 36-inch-long, instant start, Slimline Germicidal Sterilamp that may be operated at three different levels of ultraviolet intensity. The output varies depending upon the current rating of the ballast used with the lamp. It not only produces more ultroviolet for each watt of electricity consumed than previous lamps, but also provides an almost uniform level of radiation throughout life.

The new glass used for the lamp tube has a remarkable resistance to solarization, an opaquing effect that reduces the amount of ultraviolet radiation former lamps were able to emit.

CLASSIFIED ADVERTISEMENTS

HELP WANTED

Wanted—For permanent position, experienced mold designer who can start in as an assistant and later head up a mold design department for medium-sized glass container company. Reply Box 72, c/o The Glass Industry, 55 West 42nd Street, New York 18, N. Y.

AMERICAN POTASH APPOINTS DEVELOPMENT DIRECTOR

The American Potash & Chemical Corporation has announced the appointment of Daniel S. Dinsmoor, Consulting Engineer, as Director of Development. Mr. Dinsmoor, until recently a Vice President of Monsanto Chemical Company, will head the company's new Development Department and will work in the Los Angeles office in conjunction with Samuel Cottrell, Vice President in Charge of Technical Operations. In his new position, he will deal primarily with new projects related to the company's expanding operations.

Mr. Dinsmoor comes to American Potash after many years of experience in the industrial chemicals field, embracing research, development and operations. After taking his bachelor degree in chemistry at Dartmouth in 1916 and his master's at Harvard in 1917, he joined Merrimac Chemical Company, which later was acquired by Monsanto Chemical Company. He served as Vice President of Monsanto from 1943 until his resignation about a year ago to enter consulting work.

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